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Abstract: The conservation status of the Iberian lynx was found to be extremely critical by the end of the 20th Century, when only 150 individuals remained in the wild secluded into two isolated populations, Doñana and eastern Sierra Morena, both located in Andalusia. The Andalusian Government, together with a number of partners, adopted different conservation measures that received support from the European Union in the form of two LIFE-Nature conservation projects. These projects have proved essential to avoid the potential extinction of the Iberian lynx in the wild and to stabilize both free-ranging populations. Presently, in situ conservation efforts are focused on the following objectives: (1) Maintaining and expanding the two existing populations; (2) Recovering extinct population nuclei -following IUCN reintroduction criteria-, (3) Maximizing genetic diversity by "genetically connecting" the two existing populations, (4) Continuing to promote local, national and international support to ensure the recovery of this highly endangered species. Nowadays, the Sierra Morena population continues to grow -both numerically and in surface area- at an annual basis, In fact, the number of lynxes has increased from 38 adults (individuals of more than one-year-of-age) registered in 2001 to 95 in 2008. The Doñana population remains stable and a translocation program, with the ultimate goal of genetic and demographic reinforcement, is currently taking place. Also, in situ efforts are presently focused on the recovery of historical population nuclei through reintroduction programs. Preparation works are being carried out since 2005 and the first releases are scheduled to begin in 2009.

Current status of the Iberian lynx in Andalusia

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Abstract

The conservation status of the Iberian lynx was found to be extremely critical by the end of the 20th Century, when only 150 individuals remained in the wild secluded into two isolated populations, Doñana and eastern Sierra Morena, both located in Andalusia. The Andalusian Government, together with a number of partners, adopted different conservation measures that received support from the European Union in the form of two LIFE-Nature conservation projects. These projects have proved essential to avoid the potential extinction of the Iberian lynx in the wild and to stabilize both free-ranging populations. Presently, in situ conservation efforts are focused on the following objectives: (1) Maintaining and expanding the two existing populations; (2) Recovering extinct population nuclei -following IUCN reintroduction criteria-, (3) Maximizing genetic diversity by "genetically connecting" the two existing populations, (4) Continuing to promote local, national and international support to ensure the recovery of this highly endangered species. Nowadays, the Sierra Morena population continues to grow –both numerically and in surface area- at an annual basis. In fact, the number of lynxes has increased from 38 adults (individuals of more than one-year-of-age) registered in 2001 to 95 in 2008. The Doñana population remains stable and a translocation program, with the ultimate goal of genetic and demographic reinforcement, is currently taking place. Also, in situ efforts are presently focused on the recovery of historical population nuclei through reintroduction programs. Preparation works are being carried out since 2005 and the first releases are scheduled to begin in 2009.

Introduction

The Iberian lynx (*Lynx pardinus*), a species endemic to the Iberian Peninsula (Ferrer & Negro, 2004), is considered the most endangered felid in the world, as it has been catalogued as "critically endangered" by the IUCN (2003). Legal protection for the species is guaranteed by the Bern Convention, and the protection of its habitat is a priority by the European Commission (Habitat Directive 92/43). The Iberian lynx's distribution area suffered a 98% decline during the second half of the last century (Rodríguez & Delibes, 1992; Guzmán et al. 2004) and, by 2002, about 160 individuals remained, distributed into two isolated breeding populations: the Doñana Natural Space and its surroundings, and the Andújar-Cardena mountains in Eastern Sierra Morena, both in Andalusia (Guzmán et al. 2004). The Iberian lynx is a specialized predator, with more

than 90% of its diet comprised of wild rabbits (Gil-Sánchez et al. 2006). Mediterranean scrubland areas represent the optimal habitat for this species (Palomares, 2001). Current threats to the species include (1) scarcity of rabbits due to mixomatosis and rabbit haemorrhagic disease (RHD), (2) habitat destruction, and (3) human-caused mortality (road kills, leghold traps, poaching, etc.) (Guzmán et al. 2004). Given the critical situation of the species, the Andalusian Regional Ministry of Environment began working in early 2000 on measures to avoid the Iberian lynx extinction. These included: (1) to attain an accurate knowledge of the actual distribution range of the species, (2) to carry out a monitoring program of both rabbit and lynx populations, (3) to sign collaborative agreements with land owners, (4) to recover rabbit populations, (5) to

control non-natural causes of mortality, (6) to establish a captive population to help preserve current genetic diversity and (7) to ensure support from the local people that inhabit near both wild populations. Initial results from this Andalusian program allowed to determine what the actual distribution range of the Iberian lynx was and helped develop accurate population monitoring methods. By 2002, a more ambitious and participative LIFE-Nature conservation project was granted. The project, entitled "Recovery of the Iberian lynx populations in Andalusia" (LIFENAT 02/E/8609) lasted four years (2002-2006) and involved the participation of the Andalusian Regional Ministry of the Environment, the three main Andalusian hunter associations (Asociación de Titulares de Cotos de Andalucía -ATECA-, Federación Andaluza de Caza -FAC- and Asociación de Productores de Caza -APROCA-) and two conservation organizations (Ecologistas en Acción Andalucía -EEA- and CBD-Hábitat Foundation, belonging to the Spanish Environment Ministry). The main objectives of this project (which included both short- and medium-term conservation measures) were (1) to augment lynx population size, (2) to maximize the connection between isolated populations, (3) to promote habitat conservation and resources availability, (4) to improve public perception of the species, (4) to contribute to the maintenance of a genetic "pull" representative of the species, (5) to create an effective lynx population monitoring system and (6) to decrease threats for the lynx. Scientific oversight was provided by the Superior Council for Scientific Research (CSIC), Doñana's Biological Station. The main goal of this LIFE project was to stop and revert the rate of decline that had been observed during the previous decades. This included avoiding potential losses in both populations (through controlling threats and stabilizing resources availability), while increasing their carrying capacity to allow an increase of the population size. These specific goals were successfully attained, since both population nuclei could be stabilized and Sierra Morena one began increasing (LIFE project, unpublished data). Such results helped establish the basis for requesting a second LIFE-Nature project. This project, entitled "Conservation and Reintroduction of the Iberian Lynx in Andalusia" (LIFENAT 06/E/209), was granted in 2006 and will be ongoing until 2011. This new LIFE project focuses on the

following objectives: (1) Maintaining and expanding the two existing populations; (2) Recovering extinct population nuclei -following IUCN reintroduction criteria-, (3) Maximizing genetic diversity by "genetically connecting" the two existing populations; (4) Continuing to promote local, national and international support to ensure the recovery of this highly endangered species. The project counts with the participation of the Andalusian Regional Ministries of Environment, Public Works and Agriculture, the Extremadure Regional Ministry of Environment, the three main Andalusian hunter associations (ATECA, FAC and APROCA) and four conservation organizations (EEA, CBD-Hábitat Foundation, the Spanish Society for the Conservation and Study of Mammals (SECEM), and World Wildlife Fund (WWF)/Spain). The project was structured based on the "Recovery Strategy for the Iberian Lynx", presented in the II International Seminar on the Conservation of the Iberian Lynx, which was held in Córdoba in December 2004 (Olszanska & Breitenmoser, 2004). Presently, we are into the third year of this LIFE project and preliminary results indicate that the Sierra Morena population continues to increase, and also Doñana is beginning to do it, as it is currently being genetically and demographically enhanced via translocations of selected Sierra Morena individuals. In addition, firsts releases of the reintroduction of the species into areas of historical occupancy is scheduled to take place at the end of 2009.

Starting point

During 2001-2002, the actual distribution range of the Iberian lynx was studied in Andalusia. Transects searching for lynx signs (mainly scats and tracks) were performed in 366 5x5 km UTM squares, covering the known distribution area in 1988 (Rodríguez & Delibes, 1992). Lynx scats were confirmed by molecular methods (J.A. Godoy, unpublished data). Only 55 out of the 366 squares were positive, corresponding with the two previously identified nuclei: Doñana and the Andújar-Cardena mountains, in the Sierra Morena range. About 80% of the distribution area was composed of private hunting lands. Afterwards, a quantification of rabbit abundance was performed through the lynx distribution area by means of transects. Rabbit abundance ranged between 0,6 and 4 rabbits/ha.

Agreements with land owners

The establishment of agreements with land owners and with hunter societies allowed the conservation projects to perform management measures throughout the lynx distribution. A total of 125,088 Has have currently being protected via collaborative agreements with landowners: 106,359 Has signed with the Andalusian Regional Ministry of the Environment, 13,729 Has with CBD-Habitat Foundation, and 5,000 Has with WWF-Spain. In addition, the Iberian lynx presently occupies 60,000 Has of public lands.

Conservation Strategy

Both Iberian lynx LIFE conservation projects have been based on a general strategy Focused on:

- **Stabilization of existing territories:** This has been carried out focusing on the following points: (1) stabilising and increasing availability of resources through habitat improvement, and (2) decreasing actual threats for the lynx. Habitat improvement management is focused on getting optimal vegetation structure both for rabbits and lynxes (Palomares, 2001). It is mainly based on the improvement of meadows (small scrub clearances and cereal plantations) and increasing shelters for rabbits (artificial burrows, hiding areas, etc). Also, a reduction of hunting pressure on rabbits is being carried out in critical areas. Rabbit releases are being performed in areas where rabbit abundance is under 1 rabbit/Ha in autumn, which is considered the minimum necessary to sustain Iberian lynx territories (Palomares, 2001). Rabbit releases are mainly being conducted using enclosures of about 5 Has with a predator exclusion fence (that is permeable to lynxes but not to other carnivores), although soft releases in the field without enclosure have also been performed. The last tool to increase rabbit availability is the establishment of supplementary feeding stations, aiming at maintaining specific lynxes in a determined area. These stations are baited with domestic rabbits and allow managing the population in case of potential rabbit populations crashes.
- **Decreasing causes of mortality.** Threats affecting Iberian lynx are mostly human-caused, although other causes can also affect the species' population dynamic. The main human-related threats affecting Iberian lynx include poaching, road kills and drowning in wells (Rodríguez & Delibes 1992; Guzmán et al. 2004), whereas the main natural threat is infectious

diseases (Meli et al. 2009; López et al. 2009). Several measures have been implemented to control these threats. Specific surveillance against illegal hunting methods is being carried out by LIFE project staff in areas of lynx occurrence. Also, control of road kills, mainly in the Doñana population, is one of the most important issues being addressed through the current LIFE project. Part of this control is being address by the construction of wildlife underpasses and ecoducts (Figure 2), placing wildlife exclusion fences on problem roads, installing dissuasive road night lights (catadioptrics), advertising road signals and speed bumps for traffic, etc. Moreover, specific brochures and booklets have been developed to increase awareness among drivers in the Doñana area. In addition, to address the problem of lynxes drowning in wells, all known wells in areas of lynx occupancy have been covered with metallic nets. Finally, to control the risk of infectious diseases a surveillance program is being carried out throughout both Iberian lynx populations. This program includes thorough health screenings of all handled animals, and also an indirect surveillance through scat analysis.

- **Settlement of new territories:** This is performed by increasing carrying capacity and decreasing threats for the lynx. The recovery of new territories has been made using territory recovery units (TRUs) as the main methodology. TRUs are composed of different habitat improvement measures performed in about 500 Ha (mean surface area of an Iberian lynx home range). Wild rabbit releases were included in TRUs only when rabbit abundance is under 1 rabbit/Ha.
- **"Compression" of occupied areas:** This strategy works under the same premises of the abovementioned ones; i.e., by increasing carrying capacity it is possible to reduce home range surfaces, which in turn will allow a higher number of individuals to inhabit a specific area.
- **Public awareness campaigns:** These campaigns have been taking place at a regular basis since 2002, and they are developed by all partners that participate in the conservation of this species. The incorporation of the hunter societies to the communication group has been one of the most effective ways to gain access to the hunters' opinion and support. Conservation associations have also been important to bring national and local awareness regarding the situation of the species.

- **Reintroduction:** This entails a medium- to long-term aspect of the conservation strategy. The first macro-habitat analysis for the suitability of areas for potential Iberian lynx reintroduction in Andalusia was performed in 1999 (F. Palomares, unpublished data). This habitat model became the basis for further work, although resource availability was not considered in it. Given that this factor is thought to be the most important one to take into account when developing a reintroduction strategy, a more exhaustive work was needed. Initial work towards Iberian lynx reintroduction began under the first LIFE conservation project, in 2002, and it has always been based on the IUCN guidelines for reintroduction (IUCN, 1998). The detection of potential reintroduction areas in Andalusia was performed by a multi-criteria analysis (MCA). The MCA is a decision-making tool developed for complex problems that follows a logical, well-structured, decision-making process where multiple criteria are involved. The steps followed in this analysis were (1) the identification of factors determining the suitability of areas that could host Iberian lynx, (2) compilation of information on everyone of the identified factors, (3) integration of all information in a Geographical Information System (GIS) and (4) evaluation of the resulting models. The identified factors that were important in determining lynx presence included habitat features (vegetation structure, altitude and slope), resource availability (rabbit abundance and drinking points availability) and threats (proximity to urban nuclei and to communication routes). Afterwards, a Weighted Linear Combination (WLC) analysis was performed (Barredo, 1996). With this method, the suitability of a pixel is obtained as the sum of partial suitability values of every factor in that area. The final potentiality map for Andalusia took also into account the historical distribution of the species and the degree of protection degree of each area. The result was the identification of three optimal nuclei where to carry out initial Iberian lynx reintroductions in Andalusia: Guarrizas Valley, Guadalmellato Valley and Hornachuelos Natural Park. Once this map was generated, all three areas were analysed in a fine-scale comparison through hierarchical analysis of 35 variables grouped into seven groups: (1) Social attitude, (2) Possibility of integration in the current metapopulation, (3) Carrying capacity, (4) Habitat structure, (5) Possibilities of expansion to other a-priori

suitable areas, (6) Illegal persecution pressure and (7) other threats. Among the three selected areas, the Guadalmellato Valley area was selected as the best one and, thus, the first reintroduction -scheduled for late 2009- will take place at this specific site. After signing agreements with the owners, habitat management measures are already being made in the area.

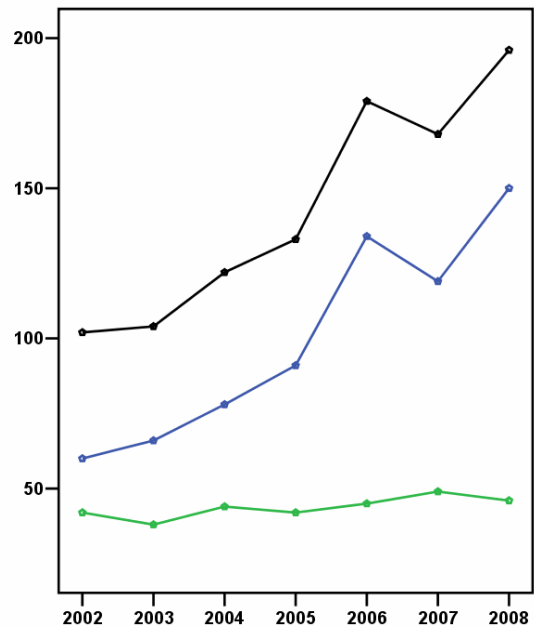


Figure 1. Annual-based evolution of the estimated total number of Iberian lynxes in Andalusia between 2002 and 2008 (black line), by subpopulations (Blue line: Sierra Morena; Green line: Doñana).

Lynx and rabbit monitoring programs

A monitoring program of both rabbits and lynxes is being carried out by the Andalusian Regional Ministry of the Environment since 2001. Rabbit abundance is continuously monitored - via transects and latrine censuses- in areas with lynx presence. A disease surveillance program (focusing mostly on RHD) is also carried out every year during critical time-periods. Iberian lynx monitoring is carried out by means of photo-trapping, radio-telemetry, direct observations and search for lynx signs (tracks, scats, etc.). Evaluation of actions undertaken at the population scale has been performed using information on inter-annual rabbit latrine survey in 2.5 km UTM squares, since its surface (625 Ha) is about the size of a breeding female home range (Ferrerias et al. 1997; Palomares, 2001). In Sierra Morena, treated squares have been compared to control ones (without management actions).

Genetic reinforcement

The low effective size has, in fact, reduced the genetic diversity of both Iberian lynx wild populations and, data shows that genetic drift has taken place in Doñana and Sierra Morena. In addition, Doñana's genetic diversity is 30% lower than that of Sierra Morena (Godoy et al. unpublished data). The most effective way to increase genetic diversity in the Doñana Iberian lynx population is via translocations of individuals from Sierra Morena. To date, two individuals from Sierra Morena have been released in Doñana, one in 2008 and the second one in 2009. Both were soft-released, being kept between 2-4 weeks in large (3-8 Has) acclimatization pens placed within the most protected environs of the Doñana area. Translocations will continue to take place until at least four individuals from Sierra Morena will settle in Doñana.

Results

Conservation strategy

- Stabilization and compression of territories, and settlement of new ones: When comparing treated squares (squares where TRUs have been performed into) with control ones, the former increase overall rabbit abundance in 6 years, has been about 100%, whereas untreated squares have not shown significant differences in rabbit abundance during the same period of time. The most effective conservation measures have been the supplementary feeding stations and the rabbit release enclosures. Yet, the most important aspect that affect rabbit population dynamics in our study area has been the RHD (Figure 5; see Calvete, this book). In Doñana, rabbit abundance has slightly increased since 2002, although the effect of the carried out actions is not clearly related to this increase. Due to landscape features, the evaluation of actions over the rabbit population, however, is much more difficult to be performed in Doñana than in Sierra Morena. A TRU has been considered successful when the rabbit increase has allowed the settlement and reproduction of an adult female, while we have considered them partially successful if settlement has been recorded but without reproduction. Most TRUs both in Sierra Morena and in Doñana have been considered successful. In Sierra Morena, eight out of the 13 established TRUs can be considered successful and two partially successful. A total of 12 new Iberian lynx territories have been established in Sierra

Morena since 2001, where the population has increased from 38 adults (considering animals over 1 year-of-age; n=60 individuals including young-of-the year) in 2002 to 95 adults (n=150 individuals including young-of the year) in 2008 (Figure 6). In Doñana, nine new female Iberian lynx territories have been established since 2002, although the effect of the habitat management units is difficult to determine. The number of individuals in the Doñana population has remained stable at approximately 31-32 adults, yet the number of territorial females has increased from 10 to 19 between 2002 and 2008 (Figure 7), while the total number of males has decreased. This is largely due to the loss of males after the 2007 Feline leukaemia (FeLV) outbreak in the Coto del Rey nuclei (López et al. 2009; Meli et al. 2009).

- Decreasing causes of mortality: Measures to control road mortality seem to be working efficiently up to now. Although road kills increased during 2003-2006, they have decreased during 2006-2009 (Figure 8; Fernández et al. this book). Control of illegal hunting methods has helped decrease the number of leghold traps and snares to almost zero. In 2008, the epidemiological surveillance program allowed to detect the first case of poisoning in an Iberian lynx. Fortunately, the perpetrator could be identified and he is currently down by law. The epidemiological surveillance program is also working effectively. Thanks to this program, which is led by staff of the Andalusian Government, the *Ex-situ* Conservation program and the University Zürich, an outbreak of feline leukemia virus that occurred in Doñana population in 2007 could be rapidly detected and controlled (López et al. 2009; Meli et al. 2009;).

- Public awareness campaigns: The outreach campaigns have made the population aware of the situation of the Iberian lynx and supportive of the proposed reintroduction in this area. Altogether, outreach efforts have largely focused on the most critical groups: hunters, farmers, local populations of Doñana, Sierra Morena and the proposed release site, and children. As part of these communication efforts, the LIFE conservation project publishes a monthly bulletin and maintains an updated webpage (www.lifeline.org). Public information is proving to be a very effective tool for local awareness and support.

- Reintroduction: Habitat management measures are presently being carried out in the Guadalquivir Valley, where the first Iberian

lynx reintroduction is scheduled to take place. Six wild-born individuals will be released during the second half of 2009. The selected method includes a soft-release technique in on-site acclimatization enclosures of approximately 4 Ha each. Most landowners in the area have already signed collaborative agreements with the Andalusian Regional Ministry of the Environment within the frame of the Iberian lynx LIFE-Nature conservation project..

Genetic reinforcement

The genetic and demographic reinforcement performed in Doñana via translocations of Sierra Morena males is still incipient. The first translocated individual was released in Doñana National Park in January 2008. It was a three-year-old male named "Baya" that belonged to the Cardeña subpopulation (Ruiz et al. this book). It was released in Coto del Rey subpopulation, (a high rabbit density place) where there were three adult females and no adult males due to the FeLV outbreak that took place in 2007. Baya immediately settled in the area and copulated with the three territorial females. All three became pregnant and gave birth to a total of eight young, of which three were still alive by the end of 2008. The introduction of Sierra Morena genes into the Doñana population is considered essential for the long-term genetic health of this wild population. In January 2009, "Caribú", a three-year-old male that originated from the Andújar subpopulation, was soft-released in Doñana's Biological Reserve, one of the best protected areas within the National Park. This placed is a low-density rabbit area where one adult female and one adult male inhabit. In contrast with the first experience, this male has not shown any interest on attempting to settle within the vicinity of the release site, and it is currently dispersing northwards out of the Doñana population in a moving considered as "homing behaviour". Experiences with other lynx species (unpublished data) point out the possibility that this individual returns to the Doñana population by itself after several months.

Safeguarding genetic diversity in captivity

Both LIFE conservation projects have helped provide all the Iberian lynx founders that presently conform the Iberian Lynx Conservation Breeding Program (Vargas et al. this book). Since 2002, 36 individuals have been brought into captivity (6 from Doñana and 30 from Sierra Morena; Table 1). From these, 24

lynxes were specifically extracted for the captive breeding program, whereas the other 10 lynxes were brought into captivity because they had problems that compromised their survival in the wild. The extraction rate was based on a model developed in order to avoid potential impacts on the population dynamics of this species (Palomares et al. 2002).

Discussion

The conservation strategy developed for the Iberian lynx in Andalusia seems to be advancing in the right way. The Sierra Morena population has experienced a substantial increase since 2001, when active conservation measures began to be implemented. The number of lynxes in this population has increased at a much higher rate than the surface area they are occupying; i.e., territories are being "compacted" and there seems to be current evidence of population saturation in Sierra Morena (LIFE project, unpublished data). The productivity is following an every-other-year cycle, probably due to the stratification of one-year-old individuals inside the population that hinder the survival of cubs born the following year. Moreover, about 70% of the juveniles are lost within their first year of life, and there have been several recorded cases of intraspecific aggression, which seems to be one of the major causes of this loss. Moreover, juveniles are currently settling in areas with very low rabbit densities or with very poor habitat structure. Population expansion seems difficult due to lack of resources in all areas surrounding the current distribution area. Nevertheless, there are suitable areas for the establishment of Iberian lynx within 15-45 km from the current Andújar-Cardena population. In fact, all available information points towards asserting that the rapidly growing Yeguas River subpopulation has motivated the foundation of a new population nucleus in Southern Castille-La Mancha Community, 15 km away from the Andalusian Sierra Morena population (Castille-La Mancha Government, unpublished data). Iberian lynx conservation efforts in Doñana have promoted the establishment of an important number of new territories outside the National Park during the period 2001-2009, which have made up for the dramatic loss of territories suffered inside the national park between 2001-2003. The key to this change of trend outside the National Park has been the awareness of the local population and the decrease in road mortality. The

number of territorial females (19) and wildborn cubs (24) recorded in Doñana in 2008 have been the maximum ever recorded in this population. We believe that all the abovementioned measures have prevented the extinction of this small population. However, more active management measures are needed to ensure the long-term conservation of this population. Reintroductions are considered to be key in moving forward towards the recovery of the endangered Iberian lynx. Once the protection and effective conservation of the currently existing populations are granted, the next step is the establishment of new free-ranging lynx populations in areas of historical occupancy. The Iberian lynx is critically endangered, and can only be recovered through hard work and solid partnerships between national and international stakeholders. The effort of politicians, biologists, scientists, veterinarians, hunters, and the whole society is sorely needed to help recover the lynx populations that roamed in the past throughout the Mediterranean forests and scrublands of the Iberian Peninsula.

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