Christine & Urs Breitenmoser recibieron sus respectivos doctorados en Zoología en la Universidad de Berna, Suiza. Desde finales de los años 80 han estado llevando a cabo proyectos de conservación de carnívoros en Suiza y en Europa. Con el fin de mejorar la coordinación de actividades de conservación en Suiza, fundaron la organización sin ánimo de lucro KORA. Desde 2001 ambos codirigen el Grupo Especialista de Felinos de la Unión Internacional para la Conservación de la Naturaleza (UICN/SSC). Durante los últimos años, han desarrollado diversas herramientas para mejorar la comunicación y la formación de especialistas en conservación de felinos, tales como la página web www.catsg.org, con información sobre las 37 especies de felinos; la biblioteca digital "Cat Library", con más de 6.000 documentos sobre conservación de felinos silvestres, y la revista "Cat News", con información sobre programas de conservación de felinos a nivel global. El Grupo Especialista de Felinos reúne a 210 especialistas de 57 países y es la única organización que trabaja globalmente, integrando conocimientos de científicos, investigadores, gestores y representantes de ONGs, con el fin de desarrollar directrices para la conservación de felinos de todo el mundo.

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We need another and a wiser and perhaps a more mystical concept of animals. Remote from universal nature, and living by complicated artifice, man in civilization surveys the creature through the glass of his knowledge and sees thereby a feather magnified and the whole image in distortion. We patronize them for their incompleteness, for their tragic fate of having taken form so far below ourselves. And therein we err, and greatly err. For the animal shall not be measured by man. In a world older and more complete than ours they move finished and complete, gifted with extensions of the senses we have lost or never attained, living by voices we shall never hear. They are not brethren, they are not underlings; they are other nations, caught with ourselves in the net of life and time, fellow prisoners of the splendour and travail of the earth.

Necesitamos otro concepto más sabio y quizás más místico sobre los animales. Alejado de la naturaleza universal y viviendo en un complejo artificio, el ser civilizado analiza a las criaturas a través de la lupa de su conocimiento, y es así como ve la pluma magnificada y toda la imagen en distorsión. Los tratamos con condescendencia por ser incompletos, por su trágico destino de haber adoptado una apariencia muy por debajo de la nuestra. Y es aquí donde erramos, erramos enormemente. Porque el animal no debe ser medido por el hombre. En un mundo más viejo y más completo que el nuestro se mueven plenos y consumados, dotados de extensiones de los sentidos que ya hemos perdido o que jamás llegamos a poseer, viviendo a merced de voces que jamás oiremos. No son hermanos, no son vasallos; son otros mundos, atrapados junto a nosotros en la red de la vida y del tiempo, compañeros prisioneros del esplendor y del arduo trabajo de la Tierra.

Henry Beston,
The Outermost House (1928)

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Conservación *Ex situ* del Lince Ibérico: Un Enfoque Multidisciplinar
Iberian Lynx *Ex situ* Conservation: An Interdisciplinary Approach

Conservación *Ex situ* del Lince Ibérico: Un Enfoque Multidisciplinar
Iberian Lynx *Ex situ* Conservation: An Interdisciplinary Approach

Astrid Vargas

Christine Breitenmoser & Urs Breitenmoser

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Astrid Vargas ha dedicado su carrera profesional a la conservación de especies amenazadas, participando tanto en aspectos de investigación y gestión como en temas de sensibilización y educación. Licenciada en Medicina Veterinaria en 1988 (Universidad Complutense de Madrid), en 1994 se doctoró en Zoología y Fisiología por la Universidad de Wyoming, EEUU, donde realizó su tesis sobre etología y biología de la conservación del turón de patas negras (Mustela nigripes), uno de los mamíferos más amenazados del planeta. Entre 2004 y 2009 coordinó el Programa Nacional de Cría en Cautividad de este mustélido, participando activamente en la reintroducción de más de 900 ejemplares en 6 áreas diferentes del Altiplano norteamericano. Durante ese mismo periodo, Astrid colaboró con la ONG "Idea Wild" apoyando proyectos de conservación de fauna en Perú, Venezuela, Guatemala, Bolivia, México y Chile. Entre 1999 y 2002, Astrid participó en proyectos de conservación en Madagascar, realizando estudios de campo sobre la fosa y el sifaka de corona dorada, y coordinando el proyecto "Iniciativa de Conservación y Gestión de Recursos Naturales en la Región de Daraina, Noreste de Madagascar", proyecto que resultó en la creación de un área protegida en dicha región en el año 2005. Desde diciembre de 2003 Astrid dirige el Programa de Conservación Ex situ del Lince Ibérico y es responsable de la gestión del centro de cría de El Acebuche, en el Espacio Natural de Doñana.

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Prólogo

El lince ibérico, símbolo de la fauna peninsular, es hoy la especie de felino más amenazada del mundo y su futuro es tan incierto que, si se cumpliesen los peores pronósticos, podría desaparecer en el plazo de diez años.

La gravedad de su situación ha hecho saltar las alarmas en todos los ámbitos, tanto nacionales como internacionales y ha conducido a incrementar los esfuerzos para tratar de evitar su extinción.

Así, en los últimos años, se han puesto en marcha nuevas medidas y proyectos, y se han reorientado iniciativas y planes ya existentes para intentar salvar al lince ibérico de su extinción.

Es el caso de la Estrategia para la Conservación del Lince Ibérico, aprobada en España en 1999, recientemente actualizada, que tiene como misión aunar la acción de todas las partes competentes en la conservación de esta especie endémica de la Península.

Sin embargo, la recuperación del lince ibérico es a la vez fin y medio, ya que su supervivencia implica intrínsecamente la del monte mediterráneo, donde el lince tiene su hábitat natural y donde ha ido perdiendo progresivamente territorio, quedándose desplazado en áreas cada vez más restringidas y aisladas.

La meta final de la Estrategia para la Conservación del Lince Ibérico es contribuir a que el lince vuelva ser una pieza funcional del ecosistema donde habita, el monte mediterráneo, para lo que se incide en el impulso de la investigación aplicada a la conservación del lince.

Esta novedosa Estrategia establece metas cuantitativas concretas y fija un calendario para conseguir que en el año 2011 el lince ibérico quede fuera de la categoría de especie "en peligro crítico", la más grave de la escala de la lista roja de la Unión Internacional para la Conservación de la Naturaleza y pasar a su catalogación como especie "en peligro". En una segunda fase, la Estrategia Nacional determina una "hoja de ruta" con el objetivo de que en el año 2020, el lince ibérico pueda pasar a ser catalogado como especie "vulnerable". El desarrollo a medio y largo plazo de nuevas poblaciones de lince ibérico es parte integrante de este proceso previsto por la Estrategia y se apoya significativamente en la cría en cautividad. A la vista de sus resultados, la puesta en marcha del Programa de Conservación *Ex situ* del Lince Ibérico en España es ya un éxito palpable, tras cinco temporadas consecutivas de reproducción, en las que se ha logrado un crecimiento exponencial de la población cautiva.

El Programa de Conservación *Ex situ* del Lince Ibérico representa de esta forma un "seguro de vida" frente a la posible extinción de la especie, preparando animales para su futura reintroducción en la naturaleza (prevista para el año 2010) y asegurando la conservación de la diversidad genética de esta especie.

Estas y otras claves para la conservación del lince ibérico fueron analizadas durante el curso que la Fundación Biodiversidad organizó en 2006 en su sede sevillana, en el que se consiguió reunir a un selecto y amplio grupo de expertos nacionales e internacionales en la materia.

Durante dos meses, científicos y técnicos de reconocido prestigio han pasado por nuestras aulas para hacernos partícipes de sus conocimientos sobre la recuperación de éste y otros felinos y trasladarnos su experiencia sobre posibles vías para sacar al lince ibérico de su gravísima situación actual.

Fruto de aquellas jornadas, y del esfuerzo de cinco años de cría para la conservación del lince ibérico, es el libro que ahora presentamos y que ha logrado recopilar entre sus páginas, de forma singular, las valiosas aportaciones de aquellos expertos que se dieron cita en Sevilla, a través de una publicación que deseamos contribuya a incrementar el conocimiento global de la comunidad científica, además de elevar la conciencia del público en general, sobre la recuperación de esta especie, tan bella como amenazada.

Josep Puxeu Rocamora
Presidente del Patronato de la Fundación Biodiversidad

Foreword

The Iberian lynx, a symbol of the fauna of the Iberian Peninsula, is today the most endangered cat species in the world. Its future is so uncertain that it may disappear in the next ten years if the worst forecasts prove right.

The gravity of the situation has raised widespread alarm on a national and international level and led to increasing efforts to try to avoid the extinction of the species.

In recent years, new measures and projects have been established, and already existing initiatives and plans aimed at preventing the extinction of the Iberian lynx have been reoriented.

The Strategy for the Conservation of the Iberian Lynx was adopted in Spain in 1999 and has recently been updated. Its mission is to bring together the actions of all the relevant players in the conservation of this species, which is endemic to the Iberian Peninsula.

However, the recovery of the Iberian lynx is both a means and an end. The survival of the species intrinsically implies the survival of Mediterranean forest and scrubland, the natural habitat of the lynx, where the species has progressively lost its territory and is being displaced to increasingly restricted and remote areas.

The final goal of the Strategy for the Conservation of the Iberian Lynx is to devote efforts so that the lynx can be a functional part of its ecosystem once again. This is carried out, among other things, by encouraging research applied to the conservation of the species.

This innovative Strategy includes specific quantitative targets and a timetable. First, the aim is to ensure that by 2011 the Iberian lynx is no longer Critically Endangered, the most serious category of threat of the IUCN Red List, and can be transferred to the category of Endangered. In a second stage, the National Strategy has established a roadmap with the objective of ensuring that the species qualifies for the category Vulnerable by the year 2020. The medium- and long-term development of new populations of Iberian lynx is an important part of the process established in the Strategy, which is significantly based on captive breeding. The Iberian Lynx *Ex situ* Conservation Programme in Spain has already proven to be successful after five consecutive breeding seasons that have led to an exponential growth of the captive population.

This Conservation Programme represents a "life insurance" against the possible extinction of the species, as it prepares animals for future reintroduction into the wild – planned for 2010 – and ensures the preservation of the genetic diversity of the species.

These key elements for the conservation of the Iberian lynx and others were analysed during the course organised in 2006 by Fundación Biodiversidad in its headquarters in Seville, which brought together a broad group of the best national

and international experts on various subjects. For two months, renowned scientists and other experts visited our classrooms to share their knowledge on the recovery of the Iberian lynx and other felid species as well as their experience on possible ways to overcome the extremely serious plight of the Iberian lynx.
The book we are presenting today is a result of the course and of the effort of five years of captive breeding for the conservation of the Iberian lynx. This publication compiles the valuable contributions of the experts who met in Seville and is intended to increase the global knowledge of the scientific community and raise awareness in the general public about the recovery of this beautiful and highly endangered species.

Josep Puxeu Rocamora
President of Board of Trustees of Fundación Biodiversidad

Prefacio

Cierra los ojos durante unos minutos e imagina qué posibles problemas podría encontrar un felino de tamaño medio en un paisaje cultivado, dominado por los seres humanos: pérdida de hábitat, disminución de presas, sequías, fuegos, persecución directa, accidentes de tráfico, fragmentación de la población, deriva genética, enfermedades, y falta de acuerdo respecto a las medidas de conservación y reparto de responsabilidades. Así era la situación del lince ibérico en 2002, cuando fue catalogado en la Lista Roja de la UICN como Críticamente Amenazado; la primera especie de felino en esa categoría. Quedaban menos de 150 linces en dos poblaciones en declive, ambas en Andalucía, una en Andújar-Cardeña, en Sierra Morena, y la otra en la región de Doñana. Desde entonces, hemos progresado, y este libro es otro paso hacia delante. No el único, pero sí una de las mejoras más obvias en los últimos años ha sido el establecimiento de un programa de cría para la conservación de esta especie.

El primer centro de cría para el lince ibérico se construyó en El Acebuche, Doñana, en 1991, pero los linces nacieron allí por primera vez en 2005. Había falta de experiencia –nunca antes había nacido un lince ibérico en cautividad— pero la gran demora en conseguirlo fue principalmente consecuencia de las profundas dudas en relación a la importancia de la cría en cautividad y de su papel en la conservación del lince ibérico. Existe un gran excepticismo entre los biólogos de campo y los conservacionistas respecto a la cría en cautividad y la reintroducción. Parte del miedo consiste en que la cría en cautividad pueda "sobreexplotar" las poblaciones silvestres, y que las reintroducciones son difíciles de llevar a cabo y conllevan una alta probabilidad de fracaso. De hecho, las experiencias de reintroducciones realizadas con linces euroasiáticos y linces canadienses extraídos de poblaciones silvestres han sido ambivalentes, y los proyectos de reintroducción de felinos nacidos en cautividad tampoco son concluyentes. Sin embargo, podemos aprender de estas experiencias, tanto de sus éxitos como de sus fracasos, y lo cierto es que la situación del lince es tan crítica que necesitamos un enfoque que abarque el máximo rango de posibilidades. Ya no es "esto o lo otro", sino "esto, y además, lo otro".

Hoy, el Programa de Cría para la Conservación no solo proporciona una "copia de seguridad" para preservar la diversidad genética de esta especie, es también una parte integral de la estrategia global para la conservación del lince ibérico. Las metas principales del Programa *Ex situ* incluyen el mantener una población cautiva bien manejada desde el punto de vista genético y proporcionar linces para programas de reintroducción. Nuevos conocimientos obtenidos gracias al trabajo con la población cautiva, tales como el estudio de patógenos y la observación y estudio de episodios agresivos entre hermanos de camada, tienen

una consecuencia directa sobre la gestión de las poblaciones cautiva y silvestre. Y, por último, pero no por ello menos importante, el programa de cría ayuda a concienciar nacional e internacionalmente acerca de la situación del lince ibérico y sus necesidades de conservación.

El proceso de conservación del lince y su programa de cría siguen un enfoque multidisciplinar, que se resalta en la gran diversidad de temas cubiertos en este libro. Gran parte de esta obra es producto de proyectos colaborativos de investigación y, como libro propiamente dicho, comenzó a tomar forma tras una serie de seminarios organizados en Andalucía en 2006 por la Fundación Biodiversidad, en colaboración con el Programa de Conservación *Ex situ*. La meta de esta serie de seminarios consistió en revisar el conocimiento que existía sobre la biología y ecología del lince, haciendo énfasis especial en su relación con el programa de cría y, a su vez, en compartir conocimientos con expertos en las disciplinas de ecología, genética, comportamiento animal, veterinaria y sanidad animal, reproducción y reintroducción. Este libro recopila gran parte de las charlas presentadas durante los seminarios de 2006 y actualiza los datos para presentar de modo integrado el trabajo de colaboración llevado a cabo en el Programa de Cría para la Conservación del lince ibérico entre 2004 y 2008.

La obra está organizada en cinco partes. La primera parte presenta una revisión sobre la situación del lince en la naturaleza y las actividades que se están llevando a cabo *in situ*. La segunda parte trata sobre aspectos genéticos, comportamiento y manejo de linces y otras especies de felinos en cautividad. La tercera parte recopila diversos trabajos sobre aspectos veterinarios, tratando temas que han ido tomando cada vez mayor importancia en la conservación de especies. La cuarta parte versa sobre la fisiología reproductiva de diversas especies de felinos, poniendo especial énfasis en los hallazgos más recientes sobre la reproducción de lince ibérico y de otras especies de linces. Por último, la quinta parte presenta una revisión sobre técnicas de reintroducción, así como casos de estudio sobre proyectos de reintroducción de felinos.

Los capítulos recopilados en esta publicación representan el trabajo de colaboración internacional que se ha llevado a cabo en pro de la conservación del lince ibérico durante los últimos cinco años, pero también presenta estudios y trabajos que se están desarrollando con otros felinos en distintas partes del mundo. Cada capítulo ha sido tratado como una publicación científica, siendo revisado por tres expertos en cada tema concreto. Aunque el idioma principal de conjunto de la obra es el inglés, los resúmenes y textos de las ilustraciones, así como el prólogo, el prefacio y el epílogo, se presentan en ambos idiomas. En conjunto, un total de 124 coautores de 10 países han participado en los 43 capítulos que contiene el libro, que incluye un epílogo de Miguel Delibes, uno de los científicos más prominentes en España, quien cierra el libro presentando su visión sobre el presente y el futuro de esta especie.

A la vez que se presenta trabajos de investigación científica en diversas disciplinas, el libro también desea llegar al público a través de su estética y ofrece más de 200 fotografías cedidas por fotógrafos nacionales e internacionales. El artista de reconocido prestigio Joe Zammit-Lucia ha diseñado específicamente para esta publicación las fotografías que aparecen en la portada y la contraportada, así como las fotografías que sirven como apertura de cada una de las secciones del libro. Los versos y citas que aparecen acompañando a cada capítulo han sido en su mayoría seleccionados por los propios autores. La diversidad de temas, junto la selección de expertos y autores de diversas partes del planeta, demuestran que el lince ibérico necesita apoyo internacional para su supervivencia, y asimismo revela cómo la sociedad global de conservacionistas está interesada e involucrada en la recuperación de esta especie, resaltando cuán necesario es el trabajar juntos para prevenir la extinción de este magnífico felino.

Urs Breitenmoser, Christine Breitenmoser y Astrid Vargas

Preface

Close your eyes and think for a few minutes about what potential threats and problems a medium-sized cat species could possibly encounter in a cultivated, human-dominated landscape: Loss of habitat, prey depletion, droughts and fire, direct persecution, traffic accidents, population fragmentation, genetic drift and inbreeding, diseases, and strong dissension regarding conservation measures and responsibilities. And no captive population. That was the Iberian lynx in 2002, when it was listed as Critically Endangered in the IUCN Red List as the first cat species ever. Less than 150 lynx remained in two declining populations in Andalucía, near Andújar-Cardeña in Sierra Morena and in the Doñana region.

Since then, we have made progress, and this book is another step forward. Not the sole, but one of the most obvious improvements in the past years has been the establishment of a conservation breeding programme. The first breeding centre for the Iberian lynx was built in El Acebuche, Doñana, in 1991, but lynx were born there only in 2005. There was a lack of experience –no Iberian lynx was ever born in captivity before– but the long delay was mainly a consequence of profound doubts regarding the importance of the conservation breeding programme and its role in the conservation of the Iberian lynx. There is a widespread scepticism among field biologists and conservationists about captive breeding and reintroduction. They fear that captive breeding may "over-exploit" the remnant populations, and that reintroductions are difficult to do and bear a high risk of failure. Indeed, the experiences with wild-to-wild reintroduction of Eurasian lynx and Canada lynx are ambivalent, and projects using captive-born cats of any species so far are not conclusive. Nevertheless, we can learn from all these earlier projects, both from their successes and failures, and the situation of the Iberian lynx is so critical that we need a comprehensive approach. It is no longer "either – or", it is "as well as".

Today, the conservation breeding programme does not only provide a safety backup for the lynx´s genetic diversity, it is an integral part of the overall conservation strategy for the species. The main goals of the *ex situ* conservation programme are to maintain a genetically well-managed captive population and to produce lynx for reintroductions. Beyond this, the conservation breeding programme provides insight into particular questions such as reproductive biology or health problems and diseases that could affect the species. Findings as a result of captive breeding, such as the study of pathogens and the observation of sibling aggression among lynx cubs have immediate consequences for the management of both the captive- and the free-ranging populations, and last but not least, the captive breeding programme helps to raise worldwide awareness for the fate of the Iberian lynx and its conservation needs.

The Iberian lynx conservation process and its captive breeding programme follow an interdisciplinary approach, emphasised by the wide range of topics covered in this

book. Largely, the book is a product of five years of collaborative research and, as a book, it began to take shape during a series of seminars on Iberian Lynx *Ex situ* Conservation, organized by the Biodiversity Foundation together with the Conservation Breeding Programme, which took place in Andalusia in autumn 2006. The goal of the seminar series was to review current knowledge on Iberian lynx biology and ecology as it relates to conservation breeding efforts and to share knowledge and experiences with experts on related fields of wild felid ecology, behaviour, genetics, health and veterinary aspects, reproduction, and reintroduction, in order to further advance the various aspects of the conservation programme. The seminar series was structured in four sessions, each lasting two days. The present book summarises the experiences presented in the talks, all of which have been updated to cover the work that has taken place in the conservation breeding programme between 2004 and 2008.

The organization of this book includes five sections. The first section presents a review of the *in situ* situation and field conservation activities. The second section deals with genetic aspects and the behaviour and husbandry of Iberian lynx in captivity. The third section compiles papers on veterinary aspects and health issues, which became increasingly important in recent years. The fourth section looks at reproductive physiology of a variety of felid species, placing special emphasis on the latest findings on lynx reproduction. Lastly, the fifth section provides an overview of reintroduction techniques and case studies of felid reintroduction projects.

The chapters compiled in this publication represent the collaborative international work carried out towards the conservation of the Iberian lynx during the past five years, but also portrays similar studies and approaches from other felid species from various areas of the world. Each chapter has been treated as a peer-reviewed paper for a scientific journal, and has been revised by three different experts in the specific subject. Although the book´s main language is English, abstracts and illustration captions from each chapter are presented in both English and Spanish; the prologue, preface and epilogue are also offered in both languages. Altogether, 124 contributors from 10 different countries have taken part in the 43 chapters, which include an epilogue by Miguel Delibes, one of Spain´s most prominent scientist, who wraps up the book presenting his vision about the present and future of the critically endangered lynx.

While presenting scientific research in a wide variety of disciplines, the book also hopes to appeal to the eye of the viewer by including more than 200 photographs contributed by national and international photographers. World renowned photographic artist Joe Zammit-Lucia, has specifically designed the photographs that appear in the front and back covers, as well as the artwork in the opening page of each of the sections. The verses and quotes that appear throughout the book have been largely selected by the authors. The variety of themes together with the selection of experts and authors from across the world demonstrates that the Iberian lynx needs international support for its survival, and also reveals how the global conservation society is interested and involved in the recovery of this species, emphasizing how much we all need to work together to prevent the extinction of this magnificent cat.

Urs Breitenmoser, Christine Breitenmoser and Astrid Vargas

Caminante, son tus huellas
el camino y nada más;
caminante, no hay camino,
se hace camino al andar.

Al andar se hace camino
y al volver la vista atrás
se ve la senda que nunca
se ha de volver a pisar.

Caminante no hay camino
sino estelas en la mar...

Antonio Machado
(1875-1939)

Biology and current status

BIOLOGÍA Y SITUACIÓN ACTUAL

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If a man walks in the woods for love of them half of each day, he is in danger of being regarded as a loafer. But if he spends his days as a speculator, shearing off those woods and making the earth bald before her time, he is deemed an industrious and enterprising citizen.

Henry David Thoreau
(1817-1862)

Photo: Antonio Sabater

Life history and ecology of the Iberian lynx

Biología y ecología del lince ibérico

Francisco Palomares

Resumen

El lince ibérico, actualmente la especie de felino más amenazada en el mundo, es un animal de tamaño medio, solitario y territorial, cuyas únicas poblaciones se encuentran en la mitad sur de la Península Ibérica. Esta especie de lince presenta una alta especialización en cuanto a sus necesidades alimenticias y de hábitat: consume casi exclusivamente conejos europeos y habita en zonas mediterráneas de monte bajo. Las hembras normalmente se reproducen una vez al año entre los 3 y 9 años de edad, y suelen sobrevivir sólo 2 de las 3-4 crías que nacen en cada camada. Los linces jóvenes abandonan el territorio materno cuando tienen entre 1 y 2 años de edad, momento en el que se dispersan en búsqueda de nuevos territorios donde asentarse como residentes. El área de campeo de los linces adultos ocupa entre 4 y 30 km^2, dependiendo de factores como el sexo y la densidad de conejos. Los machos tienden a tener mayores áreas de campeo que las hembras. Los territorios de los machos y hembras adultos pueden coincidir en gran parte, pero esto no suele ocurrir entre ejemplares adultos del mismo sexo. En la naturaleza, el lince ibérico tiene una mortalidad elevada por causas no naturales, especialmente fuera de las áreas protegidas. Existe una fuerte interferencia entre el lince y otras especies de carnívoros; los linces matan a especies de tamaño más pequeño, como los zorros, meloncillos, ginetas y gatos domésticos, lo que produce cambios en el uso del espacio y densidades más bajas de algunas especies de carnívoros más pequeños.

Palabras clave

Lince ibérico, *Lynx pardinus,* ecología espacial, reproducción, uso del hábitat, organización social

Abstract
The Iberian lynx, currently the world's most endangered felid species, is a medium-sized solitary and territorial felid whose only populations occur in the southern half of the Iberian Peninsula. This lynx species is highly specialized in its diet and habitat requirements, consuming almost exclusively European rabbits and inhabiting Mediterranean scrubland. Females normally breed once a year between 3 and 9 years of age, and only 2 of the 3 kittens of the litter usually survive. Between 1 and 2 years of age juvenile lynx abandon their mother's territory and disperse in search of new territories to settle as residents. The home ranges of adult lynx measure between 4 and 30 km^2, depending on factors such as sex and rabbit density. Males tend to have larger home ranges than females. Core areas greatly overlap between adult males and females, but there is no overlap between adult individuals of the same sex. In the wild, the Iberian lynx experiences a high mortality from non-natural causes, particularly outside protected areas. There is strong interference between lynx and other carnivore species, with lynx killing species of smaller size such as red foxes, Egyptian mongooses, common genets, and domestic cats, which results in changes in the space use and lower densities of some of the smaller carnivores.

Keywords
Iberian lynx, *Lynx pardinus,* spatial ecology, breeding, habitat use, social organization

Photo: Antonio Sabater

Figure 1. Iberian lynx breeding female emerging from a hollow tree den in Doñana.

Figura 1. Hembra reproductora de lince ibérico saliendo de su madriguera, ubicada en un árbol hueco de Doñana.

Life history and ecology of the Iberian lynx

Francisco Palomares

Introduction

The Iberian lynx *(Lynx pardinus)* is one of the 36 existing species of felids, and one of the four species of the genus Lynx in the world. Two lynx species –the Iberian lynx and the Eurasian lynx *(Lynx lynx)*– occur in Europe and Asia, and two other species –the bobcat *(Lynx rufus)* and the Canada lynx *(Lynx canadensis)*– occur in North America. The direct ancestor of the Iberian lynx was the Cave lynx *(L. pardinus spelaeus)*, which was larger than the current species and widespread in most of Europe. About one million years ago, a population of Cave lynx became isolated in south-west Europe and gave rise to the Iberian lynx as we know it today.

The coat of the Iberian lynx is variable. Whereas individuals in the Doñana area have a pattern of large dark spots and stripes on a tawny background, those in Sierra Morena have small, less distinct spots on a more or less grayish background. Males are somewhat larger than females, and have been recorded to weigh 12-14 kg, and 9-10 kg, respectively in Doñana (Beltrán and Delibes, 1993).

The Iberian lynx is currently the world's most endangered felid species (Novell and Jackson, 1996). Unlike the other lynx species, the Iberian lynx already had a small natural range which was limited to the Iberian Peninsula. After a very dramatic decrease in the size of its range in recent decades, only two populations remain in southern Spain –Doñana and Eastern Sierra Morena. The most significant factors in the population decline of the species are habitat loss and fragmentation, direct persecution, and the decline of its basic prey, the European rabbit *(Oryctolagus cuniculus)* (Rodríguez and Delibes, 1992; Palomares et al., 2002; Guzmán et al., 2004).

Feeding ecology

The Iberian lynx feeds almost exclusively on rabbits (Delibes, 1980). In several areas of the centre and south of the Iberian Peninsula where its diet has been studied, remains of rabbits have been found in 85 to 99% of the scats analyzed (Delibes, 1980; Aymerich, 1982; Beltrán and Delibes, 1991; Gil-Sánchez et al., 1997; Palomares et al., 2001). The size of the rabbits consumed changes throughout the year depending on their abundance; very young and juvenile rabbits have been found to be more present in the diet in spring and summer than in the rest of the year (Calzada, 2000; Calzada et al., 2003). Sometimes lynx also prey on geese, ducks, rats, hares, partridges, magpies, pigeons and even juvenile red and fallow deer.

To date, there is no evidence that Iberian lynx can survive and breed feeding exclusively on prey other than rabbits. Therefore, the species cannot live in areas in which rabbits are absent or very scarce.

Habitat requirements

The Iberian lynx needs the Mediterranean scrubland to live (Palomares et al., 2000); if it is not available, rocky areas with some scrubland can also be suitable (Fernández et al., 2006). The Mediterranean scrubland is

Photo: Antonio Sabater

Photo: Antonio Sabater

Photo: Antonio Sabater

Figure 2. Mediterranean forest and scrubland in Sierra Morena (a) and Doñana (b, c).

Figura 2. Bosque y matorral mediterráneo en Sierra Morena (a) y Doñana (b, c).

dominant in at least 75% of the areas where the Iberian lynx occurs and breeds regularly. In these areas, the average scrub cover is 55%. Remaining areas are usually strips of land between the scrubland and open habitats such as the edges of marshes or *dehesas* (Mediterranean savannah-like formations) (Fernández et al., 2007). Rabbit abundance must be at least between 1 and 5 rabbits/ha –in the least and most abundant seasons of the year, respectively– for breeding to take place (Palomares et al., 2001).

Dispersing individuals are not as demanding as residents in terms of habitat requirements. At that stage of their lives, they can use any kind of natural habitat as long as it is associated to some type of scrubland (Palomares et al., 2000). They are also less demanding with regard to rabbit abundance and can use areas with lower densities than those where they settle down (Palomares, 2001).

Availability of suitable breeding dens and the presence of water are also important components in lynx habitat. In Doñana, females always choose old, large hollow trees as breeding dens (at least 90 cm diameter at breast height; Fernández and Palomares, 2000) (Figure 1). In Sierra Morena, females probably breed in rock cavities and small caves. In summer, the daily movements of lynx depend on the location of water sources, where they are often sighted drinking (Palomares et al., 2001).

Therefore, the Iberian lynx needs a habitat where the dominant vegetation is the Mediterranean scrubland (Figure 2), with relatively good abundance of rabbits. Areas of Mediterranean scrubland without rabbits or areas with plenty of rabbits but without plant cover provided by scrubland or shrubland are not suitable for the

Photo: Antonio Sabater

Figure 3. Iberian lynx wild born cubs.

Figura 3. Cachorros de lince ibérico nacidos en la naturaleza.

Photo: Antonio Sabater

Figure 4. Interspecific interaction between an Iberian lynx and a red fox.

Figura 4. Interacción interespecífica entre un lince ibérico y un zorro rojo.

species. Most likely, the specie's habitat must also have places that can make good breeding dens, such as old hollow trees or rock cavities, and permanent water sources during the dry season.

Social and spatial organization

Lynx are solitary felids (Ferreras et al., 1997). It is unusual to see two individuals together apart from the female with her young during the period of dependence on the mother, which usually ends when the cubs are 7-8 months old. Males do not help to raise the kittens. Juvenile lynx abandon their mother's territory and disperse in search of new territories to settle as residents when there are between 1 and 2 years of age (Ferreras et al., 2004; Palomares et al., 1999).

The home ranges of adult lynx measure between 4 and 30 km^2, depending on factors such as sex and rabbit density (Ferreras et al., 1997; Palomares et al., 2001; Palomares, 2001). Males tend to have larger home ranges than females. Home ranges are smaller in areas where rabbits are abundant than in those where rabbits are scarcer. The areas of greatest use of resident adult lynx home ranges strongly overlap with those of individuals of the other sex, but not with territories of individuals of the same sex. Although lynx tend to be monogamous, the territories of some males may encompass those of more than one female.

Reproduction

In the wild, female lynx normally breed only between 3 and 9 years of age (Palomares et al., 2005). Breeding has been recorded in 2-year-old captive females, but the cubs seem to have lower chances of survival. Although lynx usually breed once a year, sometimes they do not breed for unknown reasons. Estrus peaks in December-January and litters are born between March and April. However, late estrus and births may occur (Fernández et al., 2002; Palomares et al., 2005). The most frequent litter size is 3 kittens, but sometimes 2 or 4 kittens are born (Figure 3). In most cases only two offspring of the litter survive until the age of dispersal.

Movements during dispersal

Lynx have dispersal limitations that make them very sensitive to barriers imposed by the construction of large infrastructures or the alteration of natural habitats (Ferreras, 2001; Ferreras et al., 2004; Revilla et al., 2004). In the Doñana area, a dispersing lynx travels an average distance of 172 km over a surface of 231 km^2 and moves a straight-line distance of 23 km away from the point of capture (Palomares et al., 1999). Lynx movements are determined by the structure and composition of habitats around breeding areas. Dispersing individuals have difficulties crossing open areas over 5 km wide. They are therefore very sensitive to fragmentation or destruction of the natural scrubland habitats they need to move about without major problems.

Mortality

Most lynx deaths in the Doñana area –at least 62%– are caused by human actions (Ferreras et al., 1992). In a radio-tracking study of more than 50 individuals, the causes of mortality recorded were the following: direct shooting (21% of deaths), illegal trapping with leg-hold traps and snares and hunting with dogs (21%), road accidents (17%) and drowning in water wells (4%). Humans appear to have been and continue to be responsible for a high proportion of deaths in Doñana as well as other areas of the specie's range.

Interactions with other carnivores and effects on prey

In Doñana, lynx often kill but do not consume other carnivore species of smaller size, including red fox *(Vulpes vulpes),* domestic cat *(Felis catus)*, Egyptian mongoose *(Herpestes ichneumon)* and common genet *(Genetta genetta)* (Figure 4) (Palomares et al., 1996; Palomares and Caro, 1999). At least in the smaller carnivores –Egyptian mongooses and genets –, these interactions lead to densities between 10 and 20 times lower in areas inhabited by Iberian lynx than areas with similar vegetation but no lynx (Palomares et al., 1996). As for interactions between Iberian lynx and Egyptian mongoose, the abundance of mongoose has proven to be directly related to the abundance of lynx. The two species only coexist in areas with low lynx density (Palomares et al., 1998). This exclusion relation is not as clear with red foxes as it is with Egyptian mongooses and genets. However, red foxes have shown to be able to use areas with higher lynx densities mainly during the resting period of lynx, thus reducing the chances of encountering them (Fedriani et al., 1999). The presence of Iberian lynx benefits rabbit populations. In spite of being predated by lynx, rabbits reach higher densities in areas with an abundance of lynx due to the control exerted by lynx on other carnivores that also consume rabbits (Palomares et al., 1995).

Final remark

Initial research studies briefly outlined here on life history and ecology of lynx, including social and spatial organization, reproduction, activity patterns or habitat use, have been basic to understanding Iberian lynx requirements and, hence, have helped develop sound conservation plans for this species. Now, when the species is critically endangered and its survival in nature depend on the performance of these plans, systematic applied research is even more important to help managers understand the response of individual free-ranging lynxes and populations to the conservation measures implemented. Adaptive management based on sound research will allow for founded modifications of conservation plans if needed.

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I heard a thousand blended notes / While in a grove I sate reclined, In that sweet mood when pleasant thoughts / Bring sad thoughts to the mind.
To her fair works did Nature link / The human soul that through me ran; And much it grieved my heart to / think What Man has made of Man.

William Wordsworth
(1770-1850)

Photo: Antonio Sabater

Status and trends of rabbit populations in the Iberian Peninsula

Estado actual y tendencias poblacionales del conejo en la Península Ibérica

Carlos Calvete

Resumen

El conejo silvestre *(Oryctolagus cuniculus L.)* es una especie clave en el ecosistema mediterráneo de la Península Ibérica. En las últimas décadas, no obstante, esta especie ha sufrido un dramático declive en su abundancia poblacional debido principalmente a la pérdida de hábitat y, en especial, a la incidencia de la mixomatosis y la enfermedad vírica hemorrágica (RHD). En la actualidad, el manejo y recuperación de las poblaciones de conejo silvestre es uno de los principales hitos en el ámbito de la conservación. Sin embargo, el impacto de la RHD en la dinámica de las poblaciones de esta especie parece ser uno de los principales obstáculos para su recuperación. En el presente capítulo, y bajo las premisas establecidas por un modelo matemático previamente desarrollado para explorar la epidemiología de la RHD, se evalúan de forma teórica los posibles resultados de la aplicación de diferentes estrategias de manejo de las poblaciones de conejo silvestre. Siguiendo los supuestos de dicho modelo, la mejora del hábitat sería el mejor modo –solo o en combinación con otras estrategias de manejo– para incrementar la densidad de conejos de forma permanente en aquellas poblaciones que ya están en equilibrio con la RHD. La mejora de aquellas poblaciones que todavía no hubieran alcanzado este equilibrio, sin embargo, parece ser compleja debido, probablemente, a las posibles interacciones entre la RHD y otros factores como la depredación. Por otro lado, el uso indebido de las translocaciones surge como un obstáculo añadido a la mejora de las poblaciones, debido a diversos mecanismos –tales como la competencia mediada por la enfermedad– que podrían perjudicar la viabilidad de las poblaciones nativas. Finalmente, se concluye que es necesario promover investigaciones futuras, tanto para evaluar las implicaciones de la RHD en la biología del conejo silvestre como para definir y desarrollar nuevos modos de gestión de la especie.

Palabras clave

Control de enfermedades, epidemiología, neumonía hemorrágico-vírica (RHD), manejo de hábitat, *Oryctolagus cuniculus*

Abstract
The European wild rabbit *(Oryctolagus cuniculus L.)* is a keystone species in Mediterranean ecosystems of the Iberian Peninsula. During the last decades wild rabbit populations have suffered a dramatic decline because of habitat loss and especially due to the incidence of myxomatosis and Rabbit Haemorrhagic Disease (RHD). Currently, enhancement of rabbit populations is a primary concern in conservation; however, the impact of RHD in rabbit population dynamics seems to be one of the major challenges to rabbit recovery. Under the theoretical insights obtained in a previous RHD epidemiology modelling approach, we evaluated the possible outcomes of several rabbit management strategies. Following model assumptions, habitat improvement was the best way –alone or in combination with other management strategies– to permanently increase rabbit densities in populations at equilibrium with RHD. The enhancement of rabbit populations in areas that had not yet reached equilibrium with RHD seemed to be more complex, likely due to possible interactions of disease with other factors like predation. The misuse of translocations arose as an added obstacle to rabbit enhancement because of underlying mechanisms, such as apparent disease-mediated competition, that could yield harmful effects on native populations. More research is needed in order to evaluate the implications of RHD on rabbit biology and to provide novel approaches to rabbit management.

Keywords
Wildlife disease control, epidemiology, Rabbit Haemorrhagic Disease (RHD), habitat management, *Oryctolagus cuniculus*

Photo: Antonio Rivas

El conejo silvestre en la Península Ibérica es un claro ejemplo de cómo una especie tan importante para el ecosistema ha sido tradicionalmente considerada una especie humilde o de carácter menor simplemente por ser común, y de cómo, esta aparente humildad, le ha hecho históricamente víctima de una gestión basada en el acerbo popular en vez de en el conocimiento científico.

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Status and trends of rabbit populations in the Iberian Peninsula

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Introduction

The European wild rabbit *(O. cuniculus L.)* is one of most important vertebrate species in Iberian Mediterranean ecosystems, where this species is native. The rabbit has a deep impact on microclimates, floral composition and invertebrate biodiversity of these ecosystems, largely contributing to their maintenance. Moreover, rabbits contribute significantly to the food supply of more than 30 predator species in the Iberian Peninsula (Delibes and Hiraldo, 1981), including highly endangered native predator species that depend on rabbit abundance. For these reasons, the wild rabbit is a primary conservation concern in the Iberian Peninsula.

Rabbits have been historically abundant in many areas of the Iberian Peninsula. Their populations, however, have been declining since the mid XX century, in part due to changes in agricultural practices and the subsequent habitat loss, yet particularly due to the impact of two viral diseases: myxomatosis in the 1950s and Rabbit Hemorrhagic Disease (RHD) at the end of the 1980s, causing two consecutive abrupt declines in wild rabbit numbers. The magnitude of rabbit populations collapse folations seems to be associated with bioclimatic factors traditionally related to habitat suitability and rabbit abundance. However, the high variability of current rabbit occurrence between and within habitats makes the relationships between mean rabbit abundance and these bioclimatic factors not so clear. This irregular distribution pattern suggests that unknown factors sometimes could be hindering and others promoting rabbit recovery at local level. Factors that could be invoked like putative and not mutually exclusive causes of this distribution pattern are: 1) variation of the impact of mortality factors (e.g. predation or hunting) at a local scale, 2) stochastic events (e.g., flooding or drought) and, especially, 3) variations in the dynamics of the wild rabbit-RHD virus system.

RHD is an infectious disease, primarily transmitted by direct contact. The etiological agent of RHD is the Rabbit Haemorrhagic Disease Virus (RHDV), a member of the family *Caliciviridae*. The main epidemiological feature of this disease is that lethality is frequently very high (about 80-90%) in rabbits older than 8 weeks of age, but less so in younger rabbits (see review of Cooke, 2002). The existence of non-pathogenic RHD-like

viruses or variation in the genetic resistance to RHD between rabbit populations have been posed as possible factors that could cause local variations in the dynamics of the wild rabbit-RHD virus system in the Iberian Peninsula. Nevertheless, to date, there is no evidence regarding the presence of protective, non-pathogenic RHD-like viruses in southern European rabbit populations or evidence of differences in the genetic resistance to the disease in Iberian populations (Alda et al., 2006). Another possibility, however, has been described by a mathematical model representing the epidemiology of RHD (Calvete, 2006a). This model suggested that the impact of RHD could be highly dependent on rabbit population dynamics. The outcome of this model were largely compatible with observed patterns of rabbit distribution in the Iberian Peninsula and showed that, the presence of a unique, highly pathogenic RHD virus can be compatible with the existence of high-density populations at equilibrium with the disease.

On the other hand, even though wild rabbits are not currently at risk of extinction, considerable efforts have been made to enhance rabbit populations for hunting and conservation purposes in the Iberian Peninsula since the arrival of RHD. These efforts have borne a considerable increase of scientific research on rabbit ecology, management and conservation, but, mainly, research has been aimed towards enhancing management of rabbit populations.

Despite these efforts, the scientific knowledge generated to date still seems to be insufficient to manage rabbit populations successfully. Indeed, the results obtained in many management experiences are negligible, and this failure is usually attributed to causes such as low habitat suitability, mortality by predation and the impact of viral diseases. Among those, mortality caused by RHD during or just after management programmes seems to be one of the more frequently events pointed as the cause of failure. Given the above mentioned reasons, although the field validation of the RHD model (Calvete, 2006a) has not been performed yet, the analysis of the possible effects of RHD on rabbit ecology and management can provide new insights into lines of future research and management efforts.

Theoretical insights into RHD and rabbit ecology

The theoretical relationships between rabbit density and habitat carrying capacity (K) are shown in Figure 1. Carrying capacity is defined as the maximum density of reproductive individuals in an area in the absence of RHD. Carrying capacity is dependent as much on intrinsic habitat features that affect rabbit productivity and survival as on extrinsic mortality factors that are unique to RHD. For simplicity, the analysis assumed a linear relationship (continuous line) between rabbit density before RHD arrival and K, with rabbit density being low at values around K_0, medium at values around K_1, and high at values around K_2.

RHD had a differential short-term initial impact on naïve populations. In Australasia, a higher initial impact of RHD was associated with higher rabbit population densities, since high densities of susceptible rabbits favoured the initial transmission of the virus. In the Iberian Peninsula, retrospective analyses resulted in similar patterns, suggesting that the short-term initial impact of the disease was higher in populations located in more suitable habitats, whereas, in populations located in medium-low suitability habitats, the disease needed several additional years to attain its highest impact (Cooke, 2002; Calvete et al., 2006). Lacking more precise knowledge about the short-term initial impact of RHD, its relationship with K was assumed to be that shown in Figure 1 (dotted line). RHD affected rabbit populations at densities higher than a threshold density value (D_{th}), a threshold that was necessary for effective virus transmission and continued persistence. The short-term initial impact of RHD was higher in denser populations (around K_2 values) and lower in populations around K_1 values.

Following the initial impact of RHD, rabbit populations tended to reach a long-term equilibrium with the disease, as predicted by the model (dashed line). In agreement with the outcomes of this model, in the range from K_0 to K_1 there was little variation in rabbit density. Rather, the highest long-term impact of RHD was reached in populations with medium-low pre-RHD density levels (around K_1 values). In contrast, disease impact was lower around K_0, due to the reduced transmission rates of the virus, and in high-density populations, around K_2 values, due to higher viral transmission rates and the consequent lower mean age of rabbit infection. When the mean age of infection is lower, a greater proportion of rabbits are infected at ages at which the RHD virus lethality is reduced, either by age resilience or the presence of maternal antibodies, resulting in a lower mortality from RHD at the population level.

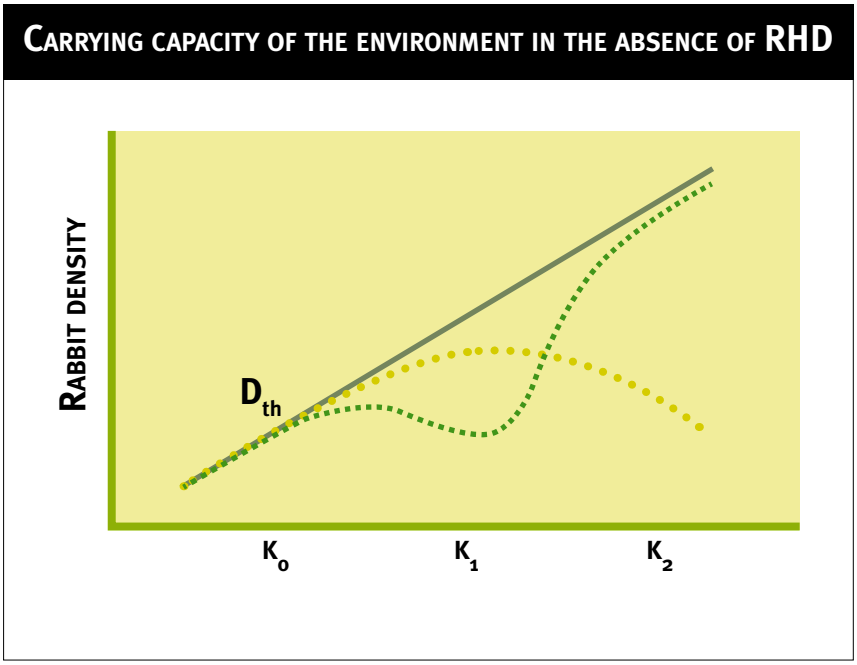

Figure 1. Theoretical relationship between rabbit density and habitat carrying capacity (K) before the arrival of RHD.
Continuous line: rabbit density before the arrival of RHD.
Dotted line: rabbit density after the short-term impact of RHD.
Dashed line: rabbit density at long- term equilibrium with RHD following the model of Calvete (2006a).
Dth: Threshold rabbit density for effective RHD-virus transmission.

Figura 1. Relación teórica entre la densidad de conejos y la capacidad de carga (K) del hábitat antes de la llegada de la enfermedad vírica hemorrágica (RHD).
Línea continua: densidad de conejos antes de la llegada de la RHD.
Línea punteada: densidad de conejos tras un corto periodo de impacto de la RHD.
Línea rayada: densidad de conejos bajo un equilibrio a largo plazo con la RHD, siguiendo el modelo de Calvete (2006a).
Dth: Umbral de densidad de conejos para un transmisión efectiva del virus de la RHD.

The dashed line in Figure 1 is actually an oversimplified way to represent the long-term impact of RHD, as it should be a cloud of points with a higher dispersion in relation to the vertical axis at values around K_1. This dispersion is determined by equilibrium between rabbit population productivity and mortality rates due to factors other than RHD. The transition of populations from short-term initial RHD impact (dotted line) to long-term equilibrium with the disease (dashed line) was likely to be highly dependent on both population dynamics and the life-history of each population. Differential transition times resulting from different population dynamics or the concurrence of factors limiting population growth at local scale may explain the currently highly variable pattern of rabbit distribution and population trends.

A extension of the theoretical predation model described by Pech et al. (1995) to incorporate the theoretical impact of RHD suggested that a gradient of possible interactions between RHD and predation impact could arise during this transition process (Calvete and Estrada, 2000). This way, the combined impacts of RHD and predation could reduce rabbit populations to lower densities than each one could do so by itself, which confirms the empirical evidence reported by Reddiex et al. (2002). In addition, the extended model suggested that the probability that rabbit populations can be maintained at low densities by predators due to a "predator-pit" phenomena could also increase in presence of RHD.

Theoretical insights into RHD and rabbit management strategies

Habitat management

The most frequent applied habitat management strategies have included scrub management to create natural pastures, construction of artificial refuges and creation of artificial pastures. However, due to the generally limited funding and logistic resources, habitat management strategies have been hardly maintained throughout time at local scale, and for example, many times artificial pastures are sowed only once at the start of management programmes.

Habitat management, is aimed to increase carrying capacity by mainly enhancing rabbit population productivity, therefore, habitat management would be the best way to promote rabbit populations in presence of RHD (Calvete, 2006a). However, following Figure 1, habitat improvement would not always yield a clear positive growth in populations. For example, we would consider a rabbit population at equilibrium with RHD located in a habitat at carrying capacity around K_0. In an attempt to enhance the rabbit population we would

perform a habitat management programme that only increased habitat carrying capacity until values around K_1. It is obvious that the results would be fairly disappointing, as no positive change in rabbit density would take place, although epidemiology of RHD would have changed dramatically. This scenario could take place under poorly funded management programmes in which long-term habitat improvement was low or, also, under poorly designed programmes in which habitat improvement was high but only during a short time. Another example would be if habitat improvement was depending on the temporary (discontinuous) availability of funding and no habitat maintenance effort was performed when funding was unavailable. In this case, rabbit population would be subjected to recurrent perturbations from its equilibrium with RHD by repeatedly increasing the impact of the disease.

Control of mortality factors and harvesting of populations

In equilibrium state with RHD, reduction of mortality alone could be useful in only some populations. However, In situations in which a previous improvement of habitat has been performed, a temporary reduction of mortality would help to achieve a quicker increase in rabbit populations. The same suitability of mortality reduction, for example predation impact reduction, could arise in rabbit populations that are not in equilibrium with the disease, since in this case predation control could help rabbits escape from predator regulation and reach the equilibrium with RHD at higher densities.

Effective harvesting reduction should yield similar results on rabbit recovery as predation impact control. Moreover, outcomes of the RHD-model suggested that a decrease in rabbit density caused by excessive harvesting pressure (hunting or capturing for translocation) may increase the impact of RHD. Thus, a sustainable harvesting is essential to rabbit maintenance. Several theoretical approaches have been carried out to estimate the impact of harvesting on rabbit populations in Iberian Peninsula in absence of RHD (Angulo and Villafuerte, 2003; Calvete at al., 2005a). The discrepancies in results of both works are, however, clear evidence that, to date, we are still far from designing sustainable harvesting plans.

Vaccination campaigns

The use of vaccination as a disease prevention method in wild rabbits has increased greatly in the past several years. Currently, wild rabbits are vaccinated against myxomatosis and/or RHD with commercial vaccines developed for use in domestic rabbits. While, in general, the efficacy of these vaccines in eliciting immune responses in wild rabbits is relatively high (at least in the case of vaccines against RHD), there is some degree of variability (Calvete et al. 2005b; Cabezas et al., 2006). Wild rabbits must be vaccinated individually; in these vaccination campaigns, rabbits are captured by trapping or ferreting, vaccinated, and, ideally, released at the site of capture. In general, the success of vaccination campaigns has been negligible, although their effectiveness has been tested in very limited short-term field experiments, and only at the individual level (Calvete et al. 2004a; Calvete et al., 2004b). More recently, a transmissible recombinant vaccine has been developed to enhance the theoretical effectiveness of future vaccination campaigns (Torres et., al 2001).

The single evaluation of the effectiveness of vaccination campaigns at the population level has been only performed by modelling and only for the case of RHD (Calvete, 2006b). This theoretical approach showed that vaccination campaigns in populations at equilibrium with the disease could yield positive or negative population growth rates, depending on rabbit population dynamics and subsequent RHD dynamics. Negative growth rates were observed in simulated populations located in habitats with carrying capacity around or under K_1 (Fig. 1). Since low density populations are the main targets of vaccination campaigns, this model suggested that current immunisation programmes may have harmful effects on many managed rabbit populations. In populations subject to immunisation, prior knowledge of RHD dynamics should be therefore essential to minimise the risk of harmful effects.

Other different scenarios would arise if vaccination campaigns were carried out in populations that had not yet reached equilibrium with the disease. In this situation, vaccination, alone or in combination with other management tools, may facilitate a quicker recovery of populations. However, many doubts arise regarding the interference of vaccination on RHD epidemiology and how rabbit population would reach equilibrium with the disease just after vaccination cessation. It is important therefore to evaluate the outcomes of vaccination campaigns performed under these scenarios.

Translocations

Rabbit translocations are frequently performed for hunting purposes, with thousands of wild or captive-born individuals being translocated every year. In addition, rabbit translocations have dramatically increased in the last years due to conservation programmes that not only work towards recuperating rabbit populations, but also use rabbits as a means to provide temporary prey to predators. It has been largely shown that short-term rabbit mortality is a critical issue in translocations, however, the few surveys carried out to evaluate the medium- to long-term success of rabbit translocations have shown that survival is generally low and that some of the main mechanisms underlying this management strategy remain unknown (Moreno et al., 2004; Cabezas and Moreno, 2007).

Following model assumptions, the effects of these translocations on restocked populations should be similar to that described for vaccination campaigns against RHD (Calvete, 2006b). In some populations at equilibrium with the disease, therefore, restockings could yield negative population growth rates due to the increase of short- medium-term RHD-mortality. Taking into account that most of translocated rabbits are temporally immunized against RHD via vaccination before their release, successive translocation trials in populations in which restocking yielded negative growth rate would derive in a process of apparent competition mediated by disease. In this scenario, restocking would increase RHD mortality among native rabbits whereas vaccinated translocated rabbits (probably not as well adapted to the new environment) survive to disease and predominate over native rabbits, deteriorating population´s long-term fitness.

Another interesting scenario would arise when the restocking was carried out in an area where RHD-virus was absent or its transmission was severely reduced because the native population was at low density. In this case, when the new restocked population increased in density after one or several breeding seasons in absence of RHD-virus transmission, the casual reintroduction of the virus or the increase of its transmission rate subsequently to rabbit density increase would cause a RHD outbreak that would dramatically lessen population density again.

Conclusion

We are currently witnessing a process of re-distribution of wild rabbit populations in the Iberian Peninsula, mainly driven by habitat loss and introduced viral diseases. Many efforts are being carried out to enhance rabbit populations, trying to integrate hunting and conservation goals. Under the assumption of the theoretical approach to the rabbit-RHD system dynamics delineated here, however, it seems that the effects of applied management strategies would be uncertain. To date, there is still a considerable lack of knowledge about actual implications of RHD on rabbit ecology, and future research efforts should be devoted to evaluating which strategy or combination would yield the best results in terms of population improvements. However, until all these matters are assessed by future research, in the light of present assumptions on RHD epidemiology the next points could contribute to optimize wild rabbit recovery programmes.

Habitat managing aimed to increase habitat carrying capacity by mainly enhancing population productivity, either alone or in combination with mortality reduction, should be the main goal of rabbit recovery strategies. The primary mechanism by which habitat carrying capacity and rabbit productivity can be increased is managing habitat to increase refuge (mainly warrens) and the quantity and the quality of available food during breeding seasons.

Following the spread of RHD, many of the highest rabbit densities are currently found to be located primarily in agricultural landscapes mainly devoted to farming annual species on what rabbits preferentially feed during the breeding season. Therefore, replicating the landscape structure of traditional agricultural systems could help rabbit recovery. On the other hand, rabbit management programmes primarily based on scrub management to create natural pasture areas or the planting of crops that are cultivated only once, are probably not sufficient for long-term increases in population productivity. In consequence, they are not sufficient for reaching a population density at which RHD impact decreases, excepting in those cases in which mortality rates are simultaneously reduced.

The main non-stochastic mortality factors that affect rabbits (excluding RHD) are myxomatosis, predation and hunting. Myxomatosis is a viral disease that was introduced into Europe in the 1950s, and remains a major cause of mortality in wild populations. To date, however, there is no effective method to control mortality from this disease. On the other hand, predation impact reduction performed by means of predator control (e.g. fox removal) yields unclear results and has harmful effects on other predator species. Nevertheless, strategies aimed to facilitate predator avoidance, such as increasing warren density, changing landscape structure to minimize predation risk

or building predator exclusion fences are measures that can be implemented for long-term reduction of predation impact in areas of concern in lynx conservation. Regarding hunting impact, effective reduction in hunting should have similar effects on rabbit recovery as predation control, with the advantage that hunting is a man-made activity that can be, or at least should be, easily reduced or even halted at the local or regional level.

For those populations that are currently at equilibrium with RHD, the long-term increase of habitat carrying capacity is the only method, either alone or in combination with other management strategies such as vaccination and/or restocking, for most negatively affected populations to reach stable densities similar to those observed prior to the introduction of RHD. In the absence of this long-term increase, the application of these other management strategies would be expected to yield only temporary positive or negative population growth rates, depending on the subsequent RHD dynamics. In contrast, in populations at densities lower than those obtained at equilibrium with the disease, the application of these management strategies for reaching equilibrium with the disease seemed to be more complex, due to possible interactions of disease with other factors, including predation, increasing, therefore, the uncertainty of results.

Until the managed rabbit population reached its final equilibrium with RHD at higher rabbit density, however, in many cases the population probably should experience a transitional process, with few changes in rabbit density but increased incidence of RHD. The duration of this hypothetical transitional process is not known, but it is probably highly dependent on population dynamics. Thus, a well-designed management programme should acquire the funding necessary for the long-term maintenance of the increased habitat carrying capacity (perhaps during 3-5 years minimum), independent of the short-term results on rabbit abundance.

Finally, for native populations that have not reached yet equilibrium with RHD, restocking may be an effective tool for recovering populations more quickly, especially in low-density populations regulated by predators. In these cases, however, apparent competition mediated by disease would have dramatic effects if population reinforcement was not sufficient to allow rabbits to escape predator regulation. Under this scenario, the combined effects of predation, apparent competition and the subsequent loss of population fitness could result in the extinction of rabbit populations. In addition, translocations carry an inherent risk of the possible transmission of new disease agents into release areas. Since their effectiveness is highly uncertain, due to the number of possible mechanisms that can cause failure or result in harmful effects on restocked populations, their application should be supervised and highly restricted in current rabbit promotion programmes in order to avoid abuse in their use as a rabbit management tool.

On the other hand, once the newly restocked population increased in density, the accidental introduction of the RHD virus would cause an outbreak of the disease, which would again dramatically lessen population density. To prevent this and to assure that the newly introduced rabbit population grows in the presence of the disease, it is necessary that rabbits and RHD-virus be translocated simultaneously. Since reservoirs and chronically infected rabbits may eliminate RHD for long periods of time, the joint translocation of rabbits and virus should be performed by translocating a relatively high number of rabbits from populations that already have reached equilibrium with RHD at high population density, and in which a high proportion of rabbits have already been infected by the virus. Conversely, the translocation of captive-born rabbits without previous contact with the virus, or the translocation of rabbits from populations in which virus transmission is reduced (low density populations), may be the worst option to attain this goal.

Nevertheless, RHD virus transmission in the wild probably depends not only on rabbit population dynamics and density but also on the density of infective viral particles in the environment. The latter, in turn, may depend on rabbit density and RHD dynamics at an unknown lag time; e.g. virus persistence in carcasses of RHD-killed rabbits in warrens. Thus, even when translocating a large number of rabbits from high density populations, it is unlikely that the newly transplanted population will immediately exhibit an equilibrium with RHD similar to that of the source population, even when the habitat and density of both populations are nearly identical. It is more likely that the new population would require several yearly cycles to reach this equilibrium, otherwise translocation would fail in the medium-term. One exciting option would be the controlled release of RHD virus during translocation and during the growth process of the new population, until the population and the virus reached equilibrium. This management practice could be applied independent of the origin of the translocated rabbits and may reduce the uncertainty of success of translocations and their dependence on initial RHD dynamics.

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If this is not done, future ages will certainly look back upon us as a people so immersed in the pursuit of wealth as to be blind to higher considerations. They will charge us with having culpably allowed the destruction of some of those records of Creation which we had it in our power to preserve; and while professing to regard every living thing as the direct handywork and best evidence of a Creator, yet, with a strange inconsistency, seeing many of them perish irrecoverably from the face of the earth, uncared for and unknown.

Alfred Russell Wallace
(1823-1913)

Photo: Antonio Sabater

A new Strategy for the Conservation of the Iberian Lynx

Una nueva Estrategia para la Conservación del Lince Ibérico

Javier Calzada, Luis Mariano González, J. Nicolás Guzmán and Borja Heredia

Resumen

Recientemente, el Grupo de Trabajo del Lince Ibérico aprobó una nueva Estrategia para la Conservación del Lince Ibérico. Esta Estrategia surge en un marco de trabajo diferente al que existía cuando se aprobó la primera Estrategia para el Lince Ibérico, en 1999. El lince ibérico está en la peor situación demográfica en la que ha estado a lo largo de su historia pero, por otra parte, nunca antes se había contado con tantos recursos humanos y económicos, ni con tanta atención política y preocupación social por la especie. La meta final de la Estrategia es que el lince ibérico sea una pieza funcional del monte mediterráneo. Para ello, la recuperación de la especie pasa tanto por gestionar con éxito las poblaciones que quedan, como por la elección y adecuación de áreas donde desarrollar proyectos de reintroducción que conduzcan al establecimiento de nuevas poblaciones silvestres. La nueva Estrategia marca un camino a seguir en el proceso de conservación y recuperación del lince ibérico, estableciendo metas numéricas concretas a lograr en un plazo determinado. Estas incluyen: 1) Estabilizar las poblaciones existentes luchando contra las amenaza para la especie. 2) Aumentar el número de linces que viven en las poblaciones silvestres. Se pretende conseguir que, para el año 2011, el lince pase de estar catalogado como "en peligro crítico de extinción, CR" a "en peligro, EN". 3) Aumentar el número de poblaciones silvestres, y lograr que para el año 2020 la especie deje de "estar en peligro, EN", para pasar a ser considerada "vulnerable, VU". Según el contexto español, la primera meta se debería conseguir a través de los Planes de Recuperación Autonómicos, que deben adoptar las líneas marcadas en la Estrategia y desarrollarlas completa y competentemente. La segunda meta es hacer crecer las poblaciones de linces hasta que, al menos una de ellas, supere los 50 individuos maduros (sin que éstos supongan más del 90% de todos los linces maduros silvestres). Si se considerase necesario, se recomienda desarrollar "Proyectos de Refuerzo e Intercambio Poblacional" para contribuir a aumentar la abundancia de linces en las poblaciones existentes. La tercera meta es conseguir que el número total de linces maduros presentes en la naturaleza sea superior a los 250 individuos maduros y que las poblaciones no muestren signos de declive. La única manera de lograrlo es mediante "Proyectos de Restauración del Hábitat y Proyectos de Reintroducción" en todas las Comunidades Autónomas de España donde el lince ibérico está presente o estuvo presente hasta hace poco.

Palabras clave

Planes de conservación, Plan de recuperación de especies, *Lynx pardinus*

Abstract
A new Strategy for the Conservation of the Iberian Lynx *(Lynx pardinus)* has recently been approved by the Spain's maximum authorities in Environmental Policy at the Sectorial Conference for the Environment. The new Strategy has been developed in a different working framework from the one that led to the first Strategy for the Conservation of the Iberian Lynx in 1999. The demographic situation of the Iberian lynx has never been worse. However, there have never been so many human and financial resources available, and the species has never been the focus of so much public attention and concern. The ultimate goal of the Strategy is to ensure that the Iberian lynx becomes a functional part of the Mediterranean scrubland habitat again. To this end, the recovery of the species involves both successfully managing the remaining populations and choosing and restoring areas to carry out reintroduction projects that will lead to the establishment of new wild populations. The new Strategy has set a roadmap for the conservation and recovery of the Iberian lynx, as well as specific numerical targets that must be met in a given period of time. These targets include: 1) Stabilize the populations by combating the causes of threat to the species; 2) Increase the number of individuals in the wild populations so that the Iberian lynx can be downlisted from Critically Endangered (CR) to Endangered (EN) by 2011; and 3) Increase the number of wild populations, so that the species can be downlisted from Endangered (EN) to Vulnerable (VU) by 2020. According to the Spanish system, the first target should be achieved through Regional Recovery Plans, which must adopt the guidelines established in the National Strategy and develop them fully and efficiently. Achieving the second goal requires increasing the number of individuals in the lynx populations until at least one of them has more than 50 mature individuals, which must not amount to more than 90% of all the wild mature individuals. If necessary, "Restocking" and "Population Exchange Projects" are recommended to help increase the abundance of lynxes in the existing populations. To achieve the third target, the combined wild populations must comprise at least 250 mature individuals and not show signs of decline. This could only be attained through "Habitat Restoration and Reintroduction Projects" carried out in all the Autonomous Communities of Spain where the Iberian lynx occurs or occurred until recent times.

Keywords
Conservation planning, Species Recovery Plan, *Lynx pardinus*

Photo: Antonio Sabater

A new Strategy for the Conservation of the Iberian Lynx

Javier Calzada, Luis Mariano González, J. Nicolás Guzmán and Borja Heredia

Introduction

Spain is a unitary state which, in fact, functions almost like a decentralized federation of regions, called "Autonomous Communities". Each of the 17 Autonomous Communities has powers to manage its own interests with a great deal of independence. The Environment is one of the areas over which Autonomous Communities have full powers. Therefore, every region is in charge of nature conservation and protects its resources with total independence. When an Action Plan is needed for the conservation of an endangered species, each Autonomous Community must draw up, adopt and implement its own Plan, which must include the necessary measures for the protection of the species in its territory (Article 31.6 of Act 4/89). In this case, the Iberian lynx *(L. pardinus)* has been listed as Endangered on a national level since 1990 (Royal Decree No. 439/90). Five Autonomous Communities in Spain where the Iberian lynx occurs or occurred until recently –Andalusia, Castille-La Mancha, Castille y Leon, Extremadura and Madrid– must therefore draw up and implement their own Species Recovery Plan to eliminate the risk of extinction of the species in their territory. However, for the species to recover successfully, Regional Plans must be designed and implemented in a coordinated and consistent way. This is done by means of National Conservation Strategies, whose purpose is to coordinate and combine the efforts of all the relevant departments and levels of government to achieve a recovery of the species.

The 2008 Strategy for the Conservation of the Iberian Lynx

The first National Conservation Strategy for the conservation of the Iberian lynx was adopted in 1999 (Dirección General de Conservación de la Naturaleza, 1999). Although the Strategy was planned to be valid for an indefinite period of time, it was decided that it should be reviewed annually and updated every four years. In 2003 no updates to the Strategy were considered necessary. However, new data available on the species –especially on its abundance, distribution and annual productivity– and the new circumstances of its management –the launch of new LIFE projects, and the Iberian Lynx *Ex situ* Conservation Programme– led the Iberian Lynx Working Group (a group of Iberian lynx experts of the national and regional environmental departments) to review and agree on a new

	1999	2007
Annual surveys were carried out	No	Yes
Estimated population size (individuals over 1 year old)	* 1,136	*** 107
No. of breeding females	* 350	*** 32
Area of occupancy	* 14,569 km²	** 2,200 km²
Area of occupancy where breeding occurs	* 10,669 km²	** 925 km²
No. of breeding populations	* 9	** 2
Range States of the Iberian lynx	* Spain and Portugal	** Spain
Spanish Autonomous Communities (administrative regions) with breeding populations	* 5	** 1
Conservation status (IUCN)	Endangered	Critically Endangered
Prior National Strategy	No	Yes
Recovery Plans approved	0	2 (Regions of Extremadura and Castille-La Mancha)
Action Plan for the Iberian Lynx in Europe	No	Yes
Iberian Lynx *Ex situ* Conservation Programme	No	Yes
LIFE Projects devoted, at least partly, to the species	2	6
Management teams exclusively devoted to the species	No	Yes
Knowledge of the specie's ecology and biology	Yes	Yes
Management Plan for the Iberian Lynx in Doñana National Park	Yes	Yes
SACs for the Iberian lynx (Natura 2000 Network)	No	SCIs approved

Table 1. Differences in conservation status, knowledge and management of the species between 1999, when the first Strategy for the Conservation of the Iberian Lynx was adopted, and 2007, when the second Strategy was drawn up. Demographic data are taken from the following studies: *Rodríguez and Delibes, 1990; ** Guzmán et al., 2005; * CMA-Junta de Andalucía (Regional Ministry for the Environment, Andalusian Regional Government), 2006.**

Tabla 1. Diferencias en el estado de la conservación, conocimientos y manejo de la especie entre 1999, año en el que fue adoptada la primera Estrategia para la Conservación del Lince Ibérico, y el año 2007, cuando se redactó la segunda Estrategia. Los datos demográficos proceden de los siguientes estudios: *Rodríguez y Delibes, 1990; ** Guzmán et al., 2005; *** CMA-Junta de Andalucía 2006.

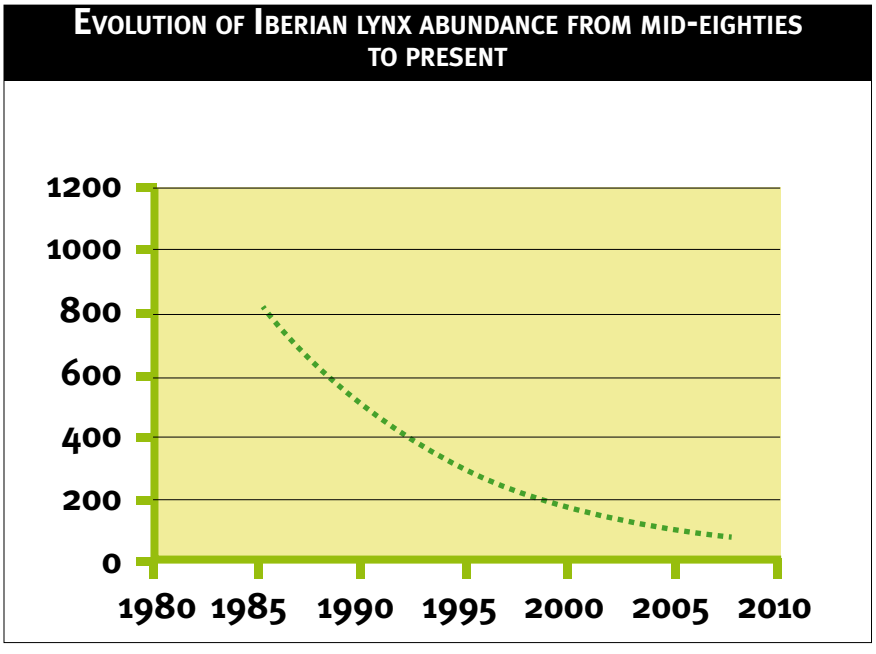

Figure 1. Evolution of Iberian lynx abundance from mid-eighties to present. The graph only considers abundance of individuals over 1-year-of-age (i.e., it does not take into account young-of-the-year). Estimates after 2001 are related exclusively to Andalusia. Data based on Rodríguez and Delibes, 1990; Castro and Palma, 1996; Guzmán et al., 2005; ; and Simon et al this book.

Figura 1. Evolución de la abundancia del lince ibérico desde mediados de los años 80 hasta el presente. El gráfico sólo tiene en cuenta la abundancia de ejemplares mayores de 1 año de edad (es decir, no incluye los cachorros ni juveniles del año). Las estimaciones posteriores al 2001 se refieren exclusivamente a Andalucía. Los datos están basados en los estudios de: Rodríguez y Delibes, 1990; Castro y Palma, 1996; Guzmán et al., 2005; ; y Simón et al, este libro.

document which has been adopted by the Iberian Lynx Working Group in 2007, and, in 2008, has been approved by the Spain's maximum authorities in Environmental Policy in the Sectorial Conference of the Environment.

A different state of affairs

The Iberian lynx is facing its worst demographic situation ever (Delibes and Calzada, 2005). In just a few years the population has declined from over a thousand individuals over 1-year-old distributed in about 10 subpopulations in different regions of Spain and Portugal (Rodríguez and Delibes, 1990; Castro and Palma, 1996) to less than two hundred individuals, most of which are grouped into two subpopulations in the region of Andalusia (Guzmán et al., 2005. See Table 1 and Figure 1). The Atlas and Red Book of Mammals of Spain, *Atlas y Libro Rojo de los Mamíferos de España* (Calzada et al., 2007) shows that, in only 16 years –between 1985 and 2001– the area of occupancy of the species has decreased by 87%, its breeding area has shrunk by 93%, the number of breeding females has declined by more than 90%, and the number of individuals over 1-year of age has fallen under 86%. These data led the IUCN to list the Iberian lynx as Critically Endangered, the highest category of threat for a species (IUCN, 2002). More recent population data obtained between 2001 and 2006 indicates some improvements (CMA-Junta de Andalucía, 2006). For instance, the Sierra Morena population is beginning to increase, while Doñana remains stable (Simón et al., this book).

Different players

In recent years, the political, social and economic attention given to the species has improved. In 1999, when the first Strategy for the Conservation of the Iberian Lynx *(L. pardinus)* in Spain was adopted, it was the first document drawn up to plan the management of the species. There was only one honorable exception, however: the Management Plan for the Iberian Lynx in Doñana National Park, drawn up many years before (Delibes et al., 1986). To date, two of the five Regional Recovery Plans have been approved, as well as an Action Plan for the species adopted by the Council of Europe, and a National Iberian Lynx *Ex situ* Conservation Programme (Delibes and Calzada, 2005). In 1999, the Sites of Community Importance (SCIs) for the Iberian lynx of the Natura 2000 Network had not been proposed yet. Today, the list has already been approved. In 1999 no attempts to breed the species in captivity had succeeded, whereas the species now breeds regularly every year in specialized centers. LIFE Projects involving the species had only been granted on two occasions, whereas the sixth one is currently under way. As a matter of fact, the latest LIFE Nature Project (see Simón et al., this book) is the most generous one ever granted so far in Europe. Besides, today there are several professional teams exclusively devoted to the management of the Iberian lynx, which was not the case in 1999 (Table 1).

In short, the current framework is totally different to the context in which the first Strategy was adopted. We know that the status of the Iberian lynx is the worst ever, but never before had so many resources been available for its management and conservation; the species has never received as much political attention, the public has never been so aware of and sensitive about its difficult plight, and never before have so many people been involved in the study, management and conservation of the Iberian lynx.

A new global commitment

The ultimate goal of the Strategy for the Conservation of the Iberian Lynx is **"to make the Iberian lynx a functional part of the Mediterranean scrubland habitat again"**. The intention is not to maintain the lynx in captive populations, or "unnatural" wild populations where the resources of the species need to be supplemented forever.

The new Strategy for the Conservation of the Iberian Lynx *(L. pardinus)* acknowledges the undeniable fact that the recovery of the lynx cannot be achieved in the territory of just one Autonomous Community. This is due to the biological and ecological characteristics of the species and its habitat requirements (Delibes, 1980; Palomares, 2001; Palomares et al., 2000, 2001). This, added to the certainty that only two breeding populations of the species remain –both in Andalusia–, means that a solid, close and honest relationship is necessary between all the different departments and levels of government to achieve a recovery of the species.

The recovery of the species clearly involves both successfully managing the remaining populations and choosing and restoring areas to carry out reintroduction projects that will lead to the establishment of new populations of Iberian lynx.

Overview of the Iberian lynx conservation and recovery process in the National Strategy

According to the Strategy, the conservation and recovery process of the Iberian lynx must absolutely involve the following steps:

Stabilize the existing populations. If the declining trend continues, the species will become extinct in the wild. To avoid this, it is urgent to stabilize the remaining wild populations. This implies eliminating the causes of threat that have been described (Dirección General de Medio Natural y Política Forestal, 2009). It must be highlighted that an increase in the abundance or range of a species in itself does not imply that it is sustainable (Clark et al., 2002). The recovery of the species can only be achieved by eliminating actual threats. However, even if all the threats affecting the wild populations disappeared and the populations remained stable, they might still become extinct because of their very small size. This could simply be caused by demographic stochasticity, an environmental disaster and/or due to problems derived from poor genetic diversity. It is therefore vital to increase the number of individuals in the remaining populations, to create new populations and to promote genetic exchange between all of them.
To meet these commitments, the Strategy has drawn up a clear roadmap with specific numerical targets that are to be achieved in specific timeframes. This is an innovative feature of the National Strategy, which also shows an attitude of political commitment. It is the first time that a strategic plan for the conservation of a species in Spain has taken on such clear, specific and measurable commitments.

Increase the number of individuals in the wild populations. The IUCN requirements for the Iberian lynx to be downlisted from Critically Endangered, CR C2a(i), to Endangered, EN, are as follows: until the population is stabilized, at least one of the two subpopulations must contain more than 50 mature individuals –adults capable of breeding–, none of the subpopulations must contain more than 90% of all mature individuals, and, in any case, there must not be extreme numerical fluctuations. Therefore, the first numerical target of the recovery process must be to increase the number of individuals in the lynx populations until at least one of them has more than 50 mature individuals*.These 50 individuals must not amount to more than 90% of all the wild mature individuals. To attain this goal, the source patches in each population should be enhanced and allowed to expand. The year 2011 was set as a deadline to meet this target at the meeting of the Iberian Lynx Working Group held on 27 March 2007, where the Strategy was discussed and adopted**.

Increase the number of wild populations. The next step will be to get the Iberian lynx downlisted from Endangered, EN, to Vulnerable, VU. For this to happen, the wild population must contain more than 250 mature individuals* and not show signs of decline. To achieve this, the habitat must be restored so that it can be used by the species and new lynx populations must be created through reintroduction projects. The National Strategy has set the year 2020 as the deadline to meet this specific target**.

In order to reach the specified goals, it is obvious that a stable captive population must be maintained to guarantee that the species will not completely disappear if the efforts to conserve the wild populations fail. In addition to providing a safety net for the species, the captive population should be able to provide individuals for Reintroduction and Restocking Projects.

**: It is difficult to calculate the number of mature individuals of wild Iberian lynx according to the definition used by the IUCN to set its categories of threat. However, a survey of the number of females holding a territory is made every year. In this species, the territory of a female is not equivalent to two mature individuals using IUCN criteria. This is because the social organization of the lynx is not always structured into monogamous pairs, and not all individuals with a territory actually breed. From a conservative approach, the target of reaching 50 mature individuals could be considered met if there were 25 breeding females; the target of reaching 250 mature individuals could be considered met if there were 125 breeding females.*

*** : Once the target is met, a taxon may be moved from a category of higher threat to a category of lower threat if none of the criteria of the higher category has been met for five years or more (IUCN 2001).*

How to meet the commitments

The first priority is to minimize the threats to the species. Unless this condition is met, the Strategy will never succeed. The Strategy contains a summary of the threats leading the species to extinction and the basic actions proposed to combat them. Yet, it is only an outline of the actual task of planning the management and conservation of the species. It is through **Regional Recovery Plans** that Autonomous Governments must adopt the guidelines set in the Strategy and develop them fully and efficiently. Each objective included in the Strategy must be broken down into more specific, realistic and measurable goals and actions related to it. These goals and actions should be adopted in the Plan with a deadline and information on who will be in charge and what budget has been planned for their implementation. More importantly, provision must be made for monitoring the actions and reviewing the Plan. A monitoring procedure is particularly necessary to check the degree of compliance with the goals; it should include a timeframe of reviews with the possibility of adjusting the actions –and even the Plan itself– to ensure that the goals are reached and thus that the species is on its way to recovery–The monitoring procedure must be designed so that it is possible to differentiate between a defect of the Plan –if the actions are implemented but do not lead to meeting the goals as expected– and a lack of compliance with the Plan– if the actions are not implemented. Regional Recovery Plans must be developed as the main tool to fight against the threats to the species and achieve the specie's recovery. Recovery Plans, however, are not the only executive plans for species conservation in Spain. There are many other local and regional action plans that are mainly targeted to reducing threats to the species, ranging from the Management Plan for the Iberian Lynx in Doñana National Park to the LIFE Project currently under way. However, it is through Recovery Plans that regional governments must plan and design the general implementation of the recovery process in each Autonomous Community. They provide an axis for all the other Plans to join in.

After minimizing the direct threats to the Iberian lynx, the most important action for the conservation of the species in the wild is to increase the number of individuals in the existing wild populations. This is aimed at protecting the species from a direct threat of extinction due to stochastic, demographic and/or environmental factors. The chances that a lynx population will disappear are inversely related to its size. In fact, over the last 30 years, all the populations of Iberian lynx with less than 50 individuals have disappeared, except for the one in Doñana (Rodríguez and Delibes, 2002, 2003). The remaining populations must grow and expand. Sometimes it may be necessary to increase the carrying capacity of source patches by "compacting" territories or by implementing **Restocking and Population Exchange Projects** (Simón et al., this book). With such few populations of Iberian lynx, the conservation of the species is unlikely to be guaranteed even if we increase the number of individuals they contain. The reason for this is that these populations might disappear simply because of environmental stochasticity –e.g., a fire, a flood or the outbreak of a new disease in the population. This risk, as well as others, would decrease with the creation of new populations through **Reintroduction Projects**. In fact, representatives of the five Spanish Autonomous Communities have agreed on the goal of achieving a new breeding population of lynx with long-term viability in each of these regions; another one will is planned to be established in Portugal (Vargas et al., this book). The commitment acquired through the National Strategy establishes that each Autonomous Community must have a Reintroduction Project under way by 2012. This implies, at least, finding and selecting a number of potential areas that can be made suitable if necessary via **Habitat Restoration Projects** so that Reintroduction Projects can be implemented with high chances of success.

One of the main tools to achieve reintroduction goals is through the **Iberian Lynx *Ex situ* Conservation Programme**, which is included in the National Strategy. The main goal of the Programme is to contribute to the specie's recovery by providing specimens born and raised in captivity fit for reintroduction into the wild (Vargas et al., 2008; Vargas et al., this book). Besides, it also offers protection in the event of a catastrophic extinction. In Andalusia there are already two dedicated Breeding Centers and a partner centre for breeding Iberian lynx in captivity. The Ministry of the Natural, Rural and Marine Environment has agreed to fund one new breeding center per Autonomous Community that has expressed and open commitment to recover the Iberian lynx in areas of historical occupancy. *In situ* and *ex situ* efforts are thus linked by MOUs that tie the building of breeding centers to preparation of habitat for lynx reintroductions. Besides the two dedicated centers that are already established in Andalusia, new centers are scheduled to be opened in Extremadura and Castille-

Steps	Goals	Main management tool
1) Stabilize current populations	Eliminate threats	Recovery Plans
2) Increase number of individuals in populations	Strengthen populations	Restocking and population exchange projects *Ex situ* Conservation Programme
3) Create new populations	Restore habitat Reintroduce lynx	Habitat restoration projects Reintroduction projects *Ex situ* Conservation Programme

Conditions for success:

- All departments in charge of environmental issues at any level of government must believe in the recovery process and participate in an active, coordinated and efficient way.
- Research applied to the conservation of the species must be promoted – especially studies aimed at assessing the outcome and efficacy of the various Plans and Projects that must be carried out.
- Society needs to be convinced of the need to conserve the Iberian lynx. The recovery process of the Iberian lynx will be difficult, long and costly, and unless there is enough support from society it will be impossible to implement it successfully.

Table 2. Steps established for the Recovery Process in the Strategy for the Conservation of the Iberian Lynx *(Lynx pardinus)*, main goals and management tools planned for the recovery of the species; conditions for success.

Tabla 2. Pasos establecidos para el Proceso de Recuperación dentro de la Estrategia para la Conservación del Lince Ibérico *(Lynx pardinus)*, objetivos principales y herramientas de manejo previstos para la recuperación de la especie; condiciones necesarias para el éxito.

La Mancha (Vargas et al., this book). These centers will each maintain approximately 8 Iberian lynx breeding pairs, that will be exchanged between facilities according to genetic criteria and that will also provide lynxes for reintroduction projects. Portugal has also joined in by building a breeding center in the Algarve region (Vargas et al., this book) while committing to sign up agreements to prepare areas for future reintroduction efforts. Table 2 shows an outline of the steps, main goals and management tools planned for the recovery of the species. This framework was established through the overview of the Recovery Process of the Strategy for the Conservation of the Iberian Lynx.

For this Strategy to be successful, all official departments in charge of environmental issues at any governmental level must believe in the recovery process and participate in an active, coordinated and efficient way. It will be necessary to promote research applied to the conservation of the species (Palomares, this book) –especially studies aimed at assessing the outcome and efficacy of the various Plans and Projects that must be carried out. However, the most important thing to do is to convince society of the need to conserve the Iberian lynx. The recovery process of the Iberian lynx will be difficult, long and costly, and unless there is enough support from society it will be impossible to implement it successfully (Jiménez, this book).

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We will either find a way, or make one.

Hanibal
(247-183 aC)

Photo: Antonio Sabater

Conservation status and Action Plan for the recovery of Iberian lynx populations in Portugal

Estado de conservación y Plan de Acción para las poblaciones de lince ibérico en Portugal

Pedro Sarmento, Joana Cruz, Catarina Ferreira, Pedro Monterroso, Rodrigo Serra, Pedro tarroso and Nuno Negrões

Resumen

Durante la segunda mitad del siglo XX, la población portuguesa del lince ibérico se distribuía en tres núcleos principales: el Valle de Sado, Malcata y Contenda-Barrancos. A lo largo de las décadas siguientes, las poblaciones de lince sufrieron una regresión significativa en estas áreas, probablemente debido a las prácticas silvícolas en gran parte del hábitat disponible, así como a la escasez de conejos a consecuencia de la introducción de enfermedades víricas. Según el último censo de linces realizado entre los años 2002 y 2004, el lince actualmente se encuentra al borde de la extinción en Portugal. El Instituto para la Conservación de la Naturaleza y Biodiversidad, consciente de la situación crítica de esta especie en Portugal, adoptó un Plan de Acción para la Conservación del Lince Ibérico con el fin de disponer de un método coherente y eficaz para la conservación del lince en territorio portugués. Este Plan de Acción se está aplicando en todos los espacios de la Red Natura 2000 situados en el área de distribución histórica del lince y que, a su vez, ofrecen condiciones apropiadas para la presencia potencial de la especie. También se están teniendo en cuenta aquellos espacios con características que podrían ser optimizadas para la supervivencia del lince. El Plan tiene como objetivo realizar actividades estratégicas de preparación para la reintroducción, con el fin de posibilitar, a largo plazo, la reintroducción del lince ibérico en áreas de distribución histórica. El Plan integra varios proyectos de conservación que están actualmente en curso y que incluyen la regeneración del hábitat y la recuperación de las especies de presa, así como la construcción de un centro de cría que se integraría en el programa global de Conservación *Ex situ* del Lince Ibérico.

Palabras clave

Restauración de hábitat, conservación *in situ*, recuperación de conejos, reintroducción, cría en cautividad

Abstract
From the first half of the 20th century onwards, the Portuguese Iberian lynx population was distributed in three major nuclei: Sado Valley, Malcata and Contenda-Barrancos. In the following decades these areas were subjected to a process that culminated in the specie's considerable regression, probably as consequence of a major allocation of potential habitat to forestry and of prey scarcity as a result of viral diseases. The most recent survey, conducted from 2002 till 2004, revealed that the species is presently on the verge of extinction. Aware of the critical situation of the Iberian lynx in Portugal, the Institute of Nature Conservation and Biodiversity developed a Conservation Action Plan for the Iberian lynx in order to provide a consistent and effective approach to conserve the species in Portuguese territory. The on-going Action Plan is being applied in all Natura 2000 Sites, located in the lynx historical distribution that present suitable characteristics for the species potential presence or landscape features that can be optimised for lynx survival and that can be relevant for the species life-cycle. The goal of this Plan is to apply pre-release strategic reintroduction activities in order to make it possible, in the long-term, the reintroduction of Iberian lynx. Integrated in the plan, there are several ongoing conservation projects, which include habitat and prey restoration and the construction of a breeding centre that will be integrated within the overall Iberian Lynx *Ex situ* Conservation Programme.

Keywords
Habitat restoration, *in situ* conservation, rabbit recovery, reintroduction, captive breeding

Photo: José María Pérez de Ayala

Conservation status and Action Plan for the recovery of Iberian lynx populations in Portugal

Pedro Sarmento, Joana Cruz, Catarina Ferreira, Pedro Monterroso, Rodrigo Serra,
Pedro Tarroso and Nuno Negrões

Introduction

A recent national survey has brought to light the critical status of the Iberian lynx (*Lynx pardinus),* in Portugal (Sarmento et al., 2009). Field evidence showed that the species is currently in a pre-extinction stage and this scenario was re-enforced by a similar operation conducted in Spain (Guzmán et al., 2005). Consequently, the Iberian lynx was classified as a Critically Endangered species under IUCN criteria in the updated version of the Portuguese Red Book of Vertebrates and in the IUCN Red List of Threatened Species (Cabral et al., 2005; IUCN, 2007). The Iberian Lynx is a vulnerable species because of its dependence on only one prey, the rabbit *Oryctolagus cuniculus*, and its narrow habitat spectrum (Delibes et al., 2000; Calvete, this book; Calzada et al., this book). The decline in rabbit populations, caused by habitat changes and viral diseases, has had a direct impact on lynx numbers as well as high rates of non-natural mortality and habitat destruction (Ferreras et al., 1992; Guzmán et al., 2005). As a result of this process, currently lynxes are essentially constrained to two isolated populations (Doñana National Park and Cardeña-Andujár), both located in the Spanish Autonomic region of Andalusia (Guzmán et al., 2005; Calzada, this book). Potentially, dispersing animals could occasionally appear in Toledo, Guadalmez river, Central Sierra Morena and Sierra del Relumbrar y Alcaraz (Alda et al., 2008).

The current dramatic status of Iberian lynx populations, associated to its ecological importance were the basis for its classification as a top priority species for conservation in Portugal. This situation was the catalyzer for the establishment of a National Conservation Action Plan (Sarmento et al., 2005), which was legally approved in 2008 (Portuguese Government Issue 12697/2008, May 6th) and whose ultimate goal is to promote the specie's recovery and conservation in national territory through the restoration of historic population nuclei through reintroduction. In this paper, we discuss the recent evolution of lynx populations in Portugal and describe the on-going and proposed conservation measures conceived to reverse the specie's decline and assure its long-term conservation in the country.

Recent history – past and present situation

A recent geographic analysis of the distribution of museum specimens, "naturalised" lynxes, skins and photographs of hunted animals, using data from 1950 to the early 1990s, put into evidence the existence of

three potentially major historical nuclei: Sado Valley (currently Cabrela-Monfurado Natura 2000 Sites), Malcata and Moura-Barrancos (Sarmento et al., 2009; see Figure 1 for geographic locations). These nuclei probably constituted the Portuguese Iberian lynx core areas in the mid-20th century. It seems that these areas were subjected to a degradation process, as a consequence of a major allocation of potential habitat to forestry and of prey scarcity as a result of viral diseases that has led the Iberian lynx towards an extinction vortex since the 1960s. By the mid 1970s, Palma (unpublished data) performed the first Portuguese scientific study on the species ecology in Serra da Malcata and attempted to describe the lynx distribution range and density in the country. A national total population of 50 individuals was estimated, which, according to the author, were distributed through Serra da Malcata, Sado Valley and Algarve.

More recently, a national lynx status survey was undertaken from 1994 to 1997 (Ceia et al., unpublished data), under the coordination of the Institute of Nature Conservation (ICN, re-designated in 2007 as the Institute of Nature Conservation and Biodiversity, ICNB), following the same criteria and methodology of the 1988 lynx Spanish survey (Rodríguez and Delibes, 1990), which had been based on personal interviews and questionnaires. Five lynx populations were estimated, distributed throughout 2,400 km^2 and harbouring a total population of 40-53 individuals. Three out of the five identified areas (Serra da Malcata, Serra de São Mamede and Guadiana) corresponded to the western extensions of the Sierra de Gata, Sierra de San Pedro, and Western Sierra Morena Spanish populations, respectively (see Figure 1).

In the beginning of this decade a new census was conducted in an Iberian cale (Guzmán et al., 2005; Sarmento et al., 2009), using only reliable methods that could undoubtedly confirm the species occurrence. For Portugal, no evidences of the species presence were obtained and the study revealed that the Iberian lynx is presently in the verge of extinction. In recent years, reliable information is becoming rarer. The last scat confirmed by DNA analysis as being from lynx origin was collected in Moura-Barrancos in late 2001 (Santos-Reis, unpublished data), and from this date forward, no other reliable information was obtained regarding the occurrence of the Iberian lynx in Portugal. This scarcity of evidence together with low habitat suitability in most of the lynx's historical range, points to a catastrophic situation for the species in Portugal (Sarmento et al., 2009). Although we cannot confirm extinction, the scenario is highly pessimistic.

On-going and future conservation actions

Aware of the considerable difficulties pointed above, the ICNB, developed a Conservation Action Plan for the Iberian lynx (CAPIL) in order to provide a consistent and effective approach to conserve the species in Portuguese territory (Portuguese Government Issue nb. 12697/2008, May 6th). The goal of this Plan is to apply pre-release strategic reintroduction activities (IUCN/SSC, 1998) in order to make possible, in the long-term, the reintroduction of the species in Portugal, and thus, to assure its viability as a fundamental element of Mediterranean ecosystems. For achieving this goal it is necessary to establish a suitable connection between *ex situ* and *in situ* actions (Vargas et al., this book). The Action Plan is being applied in all the areas of Natura 2000 Network, located in the lynx historical range, which include suitable characteristics for the presence of the species or landscape features that can be optimised for lynx survival and that can be relevant for the species life-cycle (Figure 1). In this framework we include residence, dispersal and reproduction habitats as defined by Palomares, 2001.

In situ actions – the application of the Action Plan

Conservation measures will likely be implemented at three scales of decision-making: home-range level (micro-scale), population level (macro-scale) and ecological corridors, providing a broad direction for management activities by establishing objectives and guidelines. The following managements units will be designed in order to achieve conservation (Ruediger et al., 2000; Figure 1):

• **Micro-units for lynx management (MULs):** These micro-units are intended to provide the fundamental or smallest scale for evaluation and monitoring of the effects of management actions on lynx habitat and prey. The MULs should be considered as theoretical home-ranges that should incorporate all the habitat requirements for the completion of the Iberian lynx life cycle and should be managed as if the species was present, even in case of no detection.

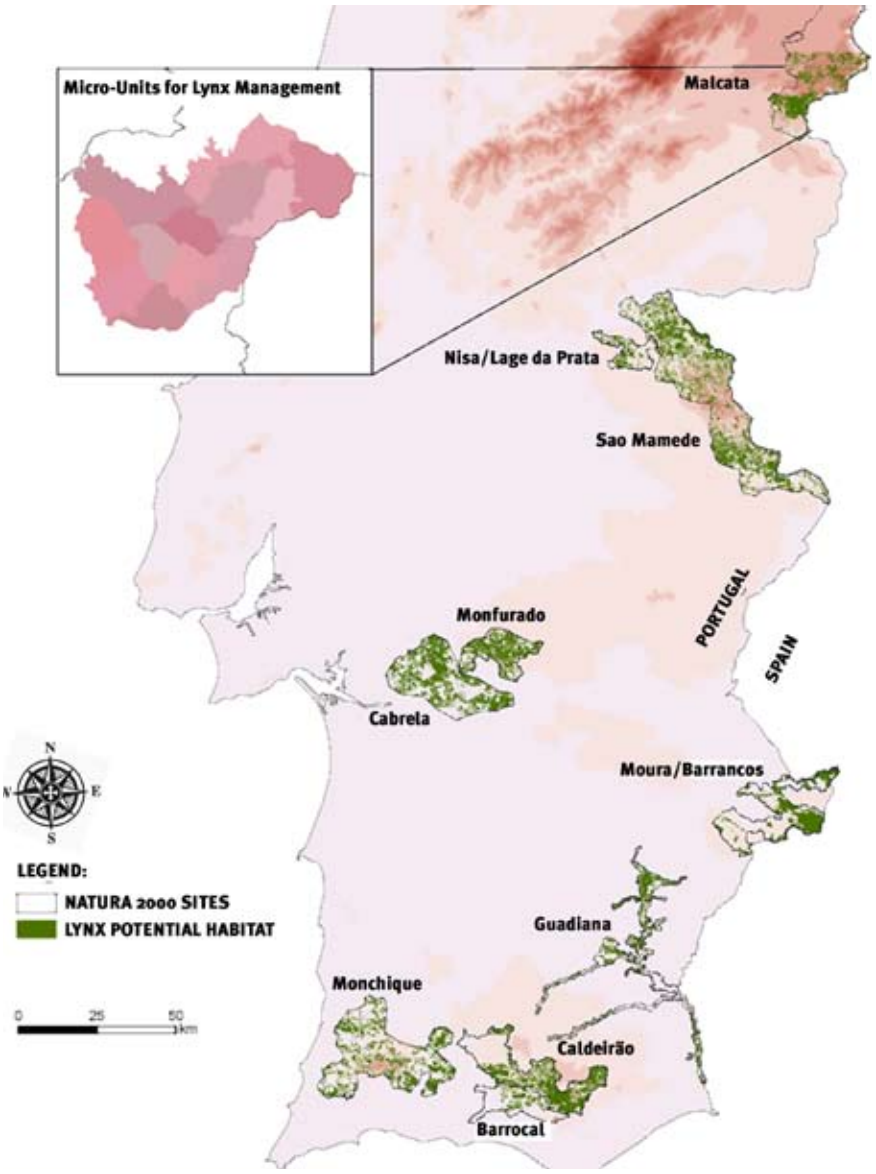

Figure 1 – Natura 2000 Sites selected for the application of the Portuguese Iberian Lynx Conservation Action Plan and examples of lynx management units for the Malcata area.

Figura 1 – Espacios Natura 2000 seleccionados para la aplicación del Plan de Acción para la Conservación del Lince Ibérico en Portugal y ejemplos de unidades de manejo del lince en el área de Malcata.

• **Macro-units for lynx management (MALs):** Action and programme planning should not be only focused at the home-range level (MULs). The landscape patterns of significant areas that correspond to potential populations should be taken into account. In this context, several MULs corresponding to theoretical populations will constitute a Macro-unit for lynx management (MALs).

• **Ecological corridors:** Dispersal is a key issue for lynx survival, since the meta-population equilibrium could only be achieved when the genetic flow between populations is maintained. Thus, the presence of linear landscape elements that warrants survivorship and movement is critical in terms of conservation.

The CAPIL actions were integrated in the Natura 2000 Network Management Plan, which will be the basic tool for conserving the habitats and species of European importance in Portugal. For the establishment of

A HABITAT TYPE	MANAGEMENT GUIDELINES
Denning habitat	Identify priority areas for land acquisition or warrant
	Recover potential areas of Mediterranean scrubland
	Promote programmes for controlling feral cats and dogs
	Promote forestry practices compatible with lynx conservation
	Establish economic incentives
	Promote sustainable rabbit hunting
	Enforce the vigilance towards illegal hunting
	Co-ordinate the decision-making process for infrastructure edification with lynx conservation
Foraging habitat	Identify priority areas for land acquisition or warrant
	Promote crop fields for rabbits
	Conduct rabbit restocking operations
	Evaluate the impact of rabbit diseases
	Promote sustainable rabbit hunting
	Enforce the vigilance towards illegal hunting
	Co-ordinate the decision-making process for infrastructure edification with lynx conservation
Corridors	Identify priority areas for land acquisition or warrant
	Stop the physical remove of scrubland vegetation and riparian habitats
	Promote sustainable rabbit hunting
	Enforce the vigilance towards illegal hunting
	Co-ordinate the decision-making process for infrastructure edification with lynx conservation

Table 1 – Natura 2000 major management guidelines for Iberian lynx conservation according to the different types of habitats.

Tabla 1 – Principales directrices de manejo de la Red Natura 2000 para la conservación del lince ibérico según el tipo de hábitat.

these measures, we mapped lynx potential habitat for all Natura 2000 Sites that had been classified with lynx presence (Figure 1). Using this data, management guidelines were defined for each habitat category according to its importance for lynx conservation (Portuguese Ministerial Council Resolution nb. 115-A/2008, July 21st; Table 1). These guidelines are being applied since 2005 for evaluating human activities that can directly or indirectly influence future lynx conservation. Currently is on-going a national evaluation on the effects of management guidelines on the conservation of natural habitats and species of European Community interest within the Natura 2000 Network areas.

On-going *in situ* conservation actions

Three major conservation projects are currently on-going:

• Habitat recovery in Serra da Malcata. Until 2007, most of the *in situ* conservation actions carried out in Portugal have concentrated in Serra da Malcata Nature Reserve where, since 1997, a continuous programme, financed by the LIFE Programme (LIFEB4-3200/99/006423) and by FEDER, for habitat and prey restoring is on-going. The main actions of this project include preventing the degradation of the Mediterranean forest, restoring land-use practices that favour rabbit presence (creation of pastures and shelters) and rabbit restocking. Several years after the systematic application of these measures it was possible to increase lynx carrying capacity at the Reserve and, as a consequence, to establish a reintroduction plan following IUCN guidelines (IUCN/SSC, 1998).

• LPN/FFI Life Project. In 2006, the League for Nature Protection (LPN), a Portuguese Non-Governmental Agency, in association with Flora and Fauna International (FFI), engaged in an EU LIFE project for the conservation of Iberian lynx in the area of Moura-Barrancos Natura 2000 Site (PTCON0053), called "Habitat recovery for the Iberian lynx in the Moura-Barrancos Natura 2000 Site" (LIFE06/NAT/P/000191). The main purpose of this project is to increase habitat suitability for lynx through the establishment of medium to long-term management agreements with

landowners and hunting reserves in order to make a rational use of natural resources and to explore game species in a sustainable way compatible with lynx conservation (for further details please go to http://www.lpn.pt).

• Odelouca dam mitigation actions. Following the assessment of water resources in the Algarve (South Portugal), the Portuguese Government has applied for financial support to the European Union for the building of a dam in the Odelouca region, a Natura 2000 Site (PTCON00037) and part of the historical range of the Iberian lynx. The package of environmental compensatory measures presented to the EU includes several actions, being habitat recovery, rehabilitation and viability analysis activities for Iberian lynx and rabbit, conversion of monocultures into Mediterranean bush, valorisation of ecological corridors between habitat patches, and the construction of a captive breeding centre for the Iberian lynx as the most relevant.

Future actions

Future *in situ* conservation actions will include a feasibility analysis for reintroduction in potentially areas, located in the south-east of Portugal, several regional projects, financed by EU funds, for habitat management and prey increasing and the establishment of a national systematic monitoring system for rabbit populations. The first measure is crucial for the success of the Action Plan since it is of critical importance that the best possible sites and release methods are utilized. The study will be conducted in three phases: 1) construction of a landscape-scale statistical model; 2) construction of a large-scale statistic model, and 3) development of a metapopulation model. Following this action, several regional projects for habitat and prey conservation will be applied in order to maintain or augment potential sites for lynx colonization.

Ex situ conservation

Portugal is represented in the Iberian Lynx Captive Breeding Team (CCCLI) through the ICNB since 2001. Based on the Spanish *Ex situ* Conservation Action Plan (Vargas et al., 2005, 2008), the ICNB has applied its global aims and objectives and developed its own *Ex situ* Conservation Plan (Serra et al., 2005), which, among other measures, foresees the construction of a captive breeding facility within the Iberian network of breeding centres and under the technical and scientific guidance of the CCCLI (Vargas et al., this book). The construction of the breeding centre in Silves (Algarve, Southern Portugal) is currently taking place and will be able to maintain up to 16 breeders coming from the captive breeding programme as of mid-2009.

Conclusions

The dramatic decline of the Iberian lynx and the critical status of its free-ranging populations in Portugal are now acknowledged by both scientific and political groups nationwide. Nevertheless, it is assured that the recovery of the Iberian lynx populations will be a considerable challenge with a high degree of uncertainty in both Iberian countries. In order to achieve the goal of restoring the species in Portugal and Spain it is necessary to apply a daring plan that will involve inter-agency and international collaboration; therefore, on-going actions involve several teams that are co-ordinately conducting a multidisciplinary approach towards Iberian lynx recovery. All the same, all agents involved in this laborious task need to be aware that, even with unlimited resources and in ideal conditions, the future of the Iberian lynx in the Iberian Peninsula is still uncertain, and only a professional attitude, coupled with social and political support, can prevent the vanishing of this majestic cat species.

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Photo: Antonio Rivas

Imagine there's no heaven / It's easy if you try / No hell below us / Above us only sky / Imagine all the people / Living for today / Imagine there's no countries / It isn't hard to do / Nothing to kill or die for / And no religion too / Imagine all the people / Living life in peace / You may say I'm a dreamer / But I'm not the only one / I hope some day you'll join us / And the world will be one / Imagine no possesions / I wonder if you can / No need for greed or hunger / A brotherhood of man / Imagine all the people / Sharing all the world / You may say I'm a dreamer / But I'm not the only one / I hope some day you'll join us /And the world will live as one.

John Lennon
(1940-1980)

Photo: Andoni Candela

Conservation of free-ranging Iberian lynx *(Lynx pardinus)* populations in Andalusia

Conservación de las poblaciones silvestres de lince ibérico *(Lynx pardinus)* en Andalucía

Miguel A. Simón, Rafael Cadenas, José María Gil–Sánchez, Marcos López-Parra, José García, Leonardo Fernández, Gema Ruiz and Guillermo López

Resumen

A finales del siglo XX se comprobó que el estado de conservación del lince ibérico era extremadamente crítico, cuando solo permanecían en la naturaleza alrededor de 150 individuos en dos poblaciones aisladas, Doñana y Sierra Morena oriental, ambas en Andalucía. La Junta de Andalucía, en colaboración con algunos socios, adoptó diferentes medidas de conservación que recibieron apoyo de la Unión Europea en forma de dos proyectos LIFE de conservación. Estos proyectos han sido esenciales para evitar la posible extinción de la especie en la naturaleza y para estabilizar ambas poblaciones silvestres. En la actualidad, los esfuerzos de la conservación *in situ* se están centrando en los siguientes objetivos: 1) Mantener y expandir las dos poblaciones existentes; 2) Crear nuevos núcleos poblacionales –siguiendo los criterios de la IUCN para las reintroducciones; 3) Maximizar la variabilidad genética mediante la "conexión genética" de ambas poblaciones; 4) Continuar promoviendo el apoyo local, nacional e internacional para garantizar la recuperación de esta especie gravemente amenazada. Hoy, la población de Sierra Morena continúa creciendo anualmente (tanto numéricamente como en superficie). De hecho, el número de individuos adultos (más de un año de edad) se ha incrementado desde los 38 registrados en 2001 hasta los 95 en 2008. La población de Doñana permanece estable, y se está llevando a cabo un programa de reforzamiento (principalmente genético, pero también demográfico). Los esfuerzos en la conservación *in situ* se están centrando también en la recuperación de nuevos núcleos poblacionales mediante programas de reintroducción. Los trabajos de preparación se están llevando a cabo desde 2005 y las primeras sueltas están programadas para el 2009.

Palabras clave

Recuperación, diversidad genética, refuerzo demográfico, reintroducción

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 programme, 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 programmes. Preparation works are being carried out since 2005 and the first releases are scheduled to begin in 2009.

Keywords

Recovery, genetic diversity, demographic reinforcement, reintroduction

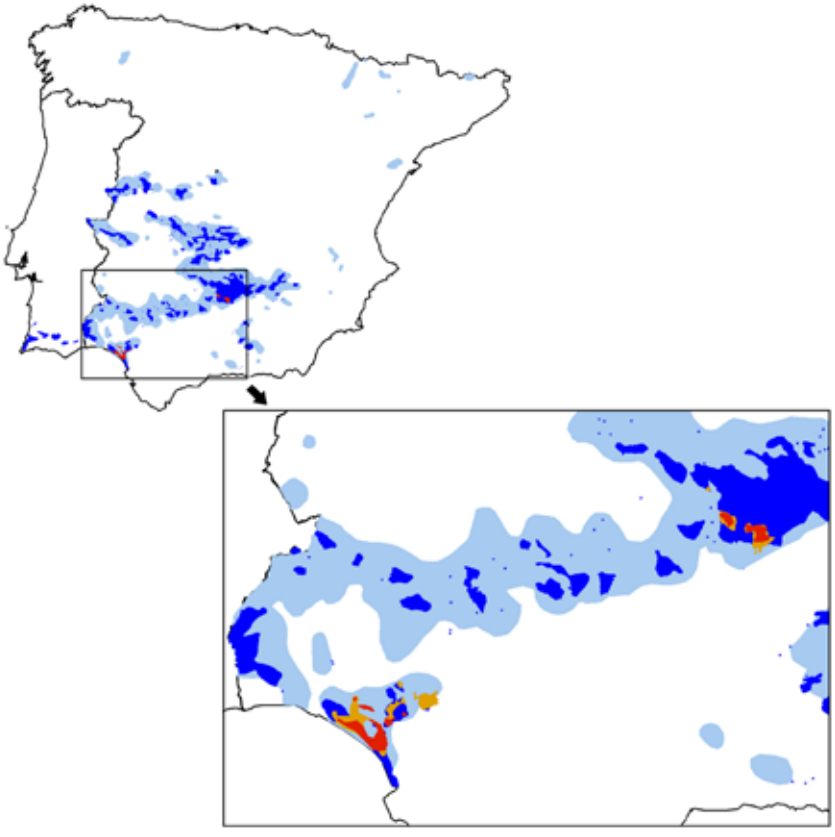

Figure 1. Iberian lynx distribution range in the 60's (only Spain; pale blue) (Rodríguez & Delibes, 1990), in the early 90's (dark blue) (Rodríguez & Delibes, 1990; Castro & Palma, 1996), in 2002 (red)(Guzmán et al., 2004), and in 2008 (orange) (LIFE project unpublished data).

Figura 1. Área de distribución del lince en los años 60 (sólo en España; azul pálido) (Rodríguez y Delibes, 1990), a principios de los 90 (Azul oscuro) (Rodríguez & Delibes, 1990; Castro & Palma, 1996) y en 2002 (rojo) (Guzmán et al., 2004).

Conservation of free-ranging Iberian lynx *(Lynx pardinus)* populations in Andalusia

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Introduction

The Iberian lynx *(Lynx pardinus)*, a species endemic to the Iberian Peninsula (Ferrer & Negro, 2004), is currently endangered in Spain and virtually extinct in Portugal (Sarmento et al., this book). It 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 Iberian lynx is granted by the Bern Convention, and the protection of its habitat, the Mediterranean scrubland, is a considered a priority by the European Commission (Habitat Directive 92/43). Although it is known that the Iberian lynx inhabited throughout the Iberian Peninsula, its distribution area suffered a 98% decline during the second half of the last century (Rodríguez et al., 1992; Guzmán et al., 2004; Calzada et al., this book) and, by 2002, about 170 individuals remained, distributed into two isolated breeding populations: the Doñana Natural Space and its surrounding biosphere reserve, and the Andújar–Cardeña mountains in Eastern Sierra Morena, both in Andalusia (Guzmán et al., 2004; see Figure 1). The Iberian lynx is a specialized predator, with more than 90% of its diet comprised of wild rabbits (Gil–Sánchez et al., 2006; Palomares, this book "a"; Calvete, this book). Mediterranean scrubland areas represent the optimal habitat for this species (Palomares, 2001; Palomares, this book "a"). Current threats to the species include 1) scarcity of rabbits due to mixomatosis and rabbit haemorrhagic disease (RHD) (Calvete, this book); 2) habitat destruction, and 3) human–caused mortality (road kills, leghold traps, poaching, etc.) (Guzmán et al., 2004).

Given this critical scenario, in early 2000 the Andalusian Regional Ministry of Environment began working 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 programme 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 programme allowed to determine what was the actual distribution range of the Iberian lynx 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; 5) to contribute to the maintenance of a genetic "pull" representative of the species; 6) to create an effective lynx population monitoring system, and 7) 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 Extremadura 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.

Materials and methods

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, 1990). 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–Cardeña 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.

Figure 2.
(A). Fauna underpass placed in a road of Doñana area.
(B). Construction of speed bumps in a road of Doñana area.

Figura 2.
(A). Paso de fauna en una carretera de Doñana. (B). Construcción de resaltos en una carretera de Doñana.

Figure 3. Well covered with a metallic net protected from the entrance of Iberian lynxes. Drowning in wells was detected as a relevant cause of mortality during the 90's.

Figura 3. Pozo cubierto con una malla metálica para evitar la caída de linces. El ahogamiento en pozos se detectó como una causa relevante de mortalidad durante los años 90.

Agreements with landowners

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, 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 specie'spopulation 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 includes mortalilty due infectious diseases (Meli et al., 2009; López et al., this book; Meli et al., this book). 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 addresed by the construction of wildlife underpasses and

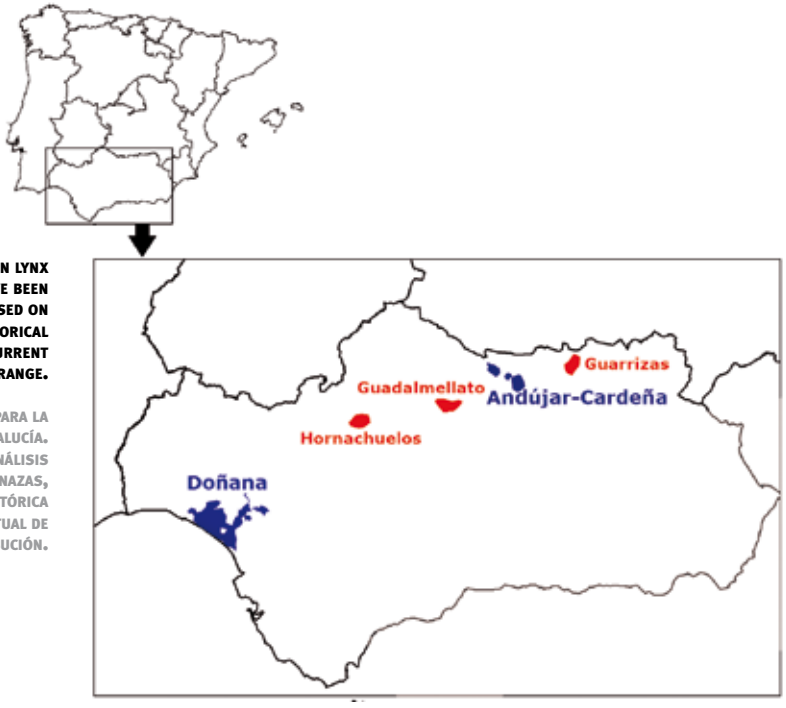

Figure 4. Optimal areas (in red) for Iberian lynx reintroduction in Andalusia. Areas have been selected by the multi–criteria analysis based on habitat, threats, resources availability, historical distribution and protection degree. In blue, current distribution range.

Figura 4. Áreas óptimas (en rojo) para la reintroducción del lince ibérico en Andalucía. Las áreas se han seleccionado por un análisis multi–criterio en función del hábitat, amenazas, disponibilidad de recursos, distribución histórica y grado de protección. En azul, área actual de distribución.

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 (Figure 3). Finally, to control the risk of infectious diseases (López et al., this book; Meli et al., this book) a surveillance programme is being carried out throughout both Iberian lynx populations. This programme includes thorough health screenings of all handled animals (Martínez et al., this book), 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 hunter's 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 become 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 being 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 (Figure 4) 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. Ever since after signing agreements with the owners, habitat management measures are already being made in the area.

Lynx and rabbit monitoring programmes

A monitoring programme 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 programme (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, radiotelemetry, 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 (Ferreras et al., 1997; Palomares, 2001). In Sierra Morena, treated squares have been compared to control ones (without management actions).

Genetic and demographic reinforcement via translocation of selected individuals

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 (Godoy et al., this book). In addition, Doñana's genetic diversity is 30% lower than that of Sierra Morena (Godoy et al., this book). The most effective way to increase genetic diversity in the Doñana Iberian lynx population is via translocations of individuals from Sierra Morena (Palomares, this book "b"; Godoy et al., this book). 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 affects 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

Individual	Year	Age	Population	Individual	Year	Age	Population
Aura	2002	<1	DON	Candiles *	2006	<1	SMO
Saliega	2002	<1	SMO	Caña	2006	<1	SMO
Garfio	2003	3	SMO	Cardo	2006	<1	SMO
Cromo *	2003	<1	SMO	Ceniza	2006	<1	SMO
Fran *	2003	1	SMO	Córdoba	2006	<1	SMO
Jub	2003	3	SMO	Coscoja	2006	<1	SMO
Adelfa	2004	<1	SMO	Cuco	2006	<1	SMO
Alhucemas	2004	<1	SMO	Al–Andalus	2007	3	SMO
Aliaga	2004	<1	SMO	Alfonso *	2008	10>	SMO
Almoradux	2004	<1	DON	Azuel *	2008	Unkn.	SMO
Artemisa *	2004	<1	SMO	Calabacín *	2008	2	SMO
Arcex	2005	1	SMO	Cascabel	2008	2	SMO
Beta	2005	<1	SMO	Charqueña	2008	2	SMO
Biznaga	2005	<1	SMO	Era	2008	<1	SMO
Boj	2005	<1	DON	Esparto	2008	<1	SMO
Azahar *	2006	2	SMO	Espina	2008	<1	DON
Bandolero	2006	1	SMO	Estela II	2008	<1	DON
Barraca *	2006	1	SMO	Damán II	2009	2	SMO

Table 1. Iberian lynx individuals extracted from the field by the LIFE conservation project to be incorporated as founders of the *Ex situ* Conservation Programme (* = individuals considered to have limited potential for survival in the wild at the time of capture).

Tabla 1. Ejemplares de lince ibérico extraídos de la naturaleza por el Proyecto LIFE para ser incorporados al Programa de Conservación *ex situ* del Lince Ibérico (*=individuos extraídos por tener un bajo potencial de supervivencia en la naturaleza en el momento de captura).

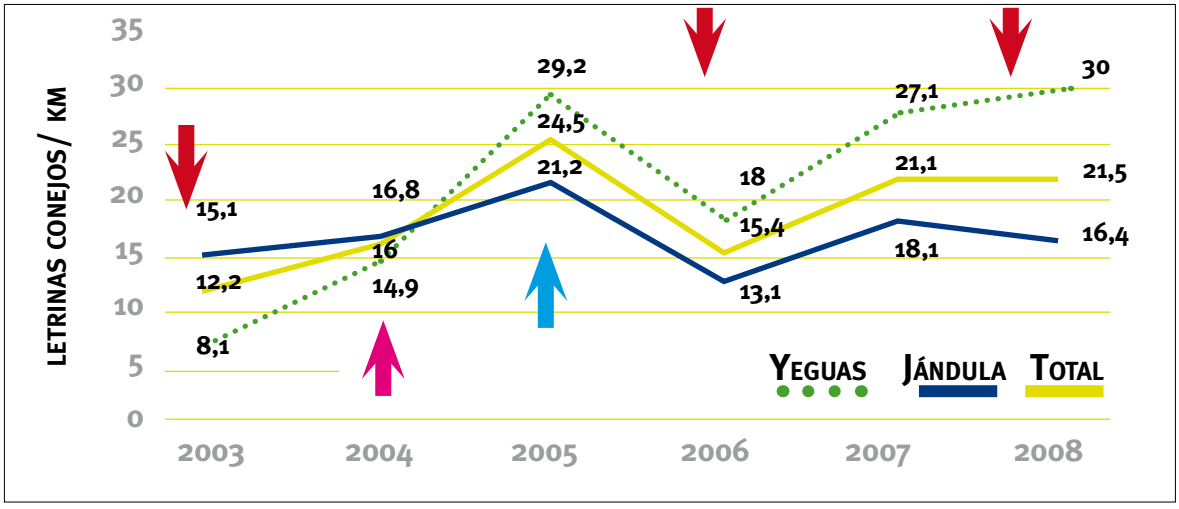

Figure 5. Evolution of the rabbit relative abundance in 2.5 Km UTM squares in the Iberian lynx occupancy area (n = 28squares). The pink arrow marks the beginning of the supplementary feeding programme in the three corresponding squares. The blue arrow marks the beginning of the LIFE project activities. Red arrows mark Rabbit haemorrhagic disease outbreaks.

Figura 5. Evolución de la abundancia relativa de conejos en unidades UTM en cuadrados de 2,5km en el área de distribución del lince (n = 28 cuadrados). La flecha rosa marca el inicio del programa de alimentación suplementaria en los tres cuadrados correspondientes. La flecha azul marca el inicio de las actuaciones del LIFE. Las flechas rojas marcan las epizootias de la Enfermedad Hemorrágica del conejo.

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

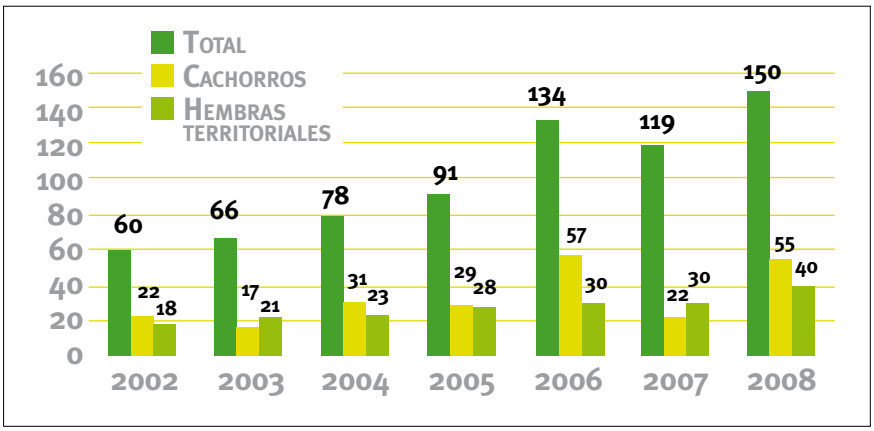

Figure 6. Evolution of the Iberian lynx population in Sierra Morena between 2002 and 2008: estimated total number of individuals, cubs and territorial females.

Figura 6. Evolución de la población de Sierra Morena entre 2002 y 2008: número total de individuos estimados, cachorros y hembras territoriales.

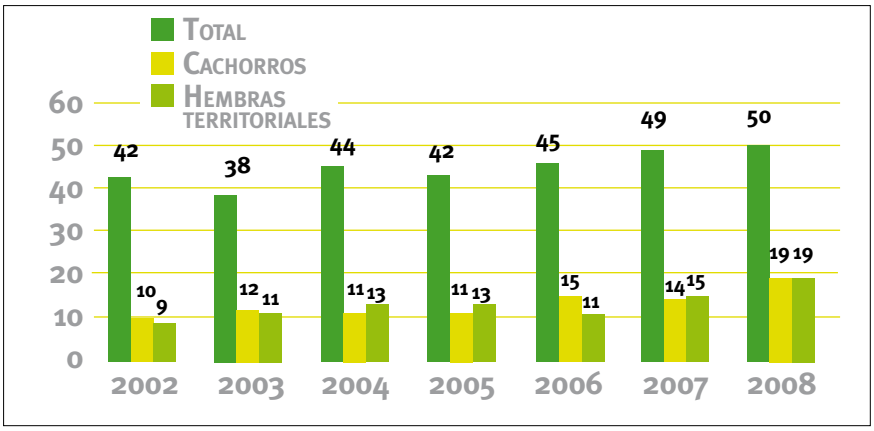

Figure 7. Evolution of the Iberian lynx population in Doñana between 2002 and 2008: estimated total number of individuals, cubs, and territorial females.

Figura 7. Evolución de la población de Doñana entre 2002 y 2008: número total de individuos estimados, cachorros y hembras territoriales.

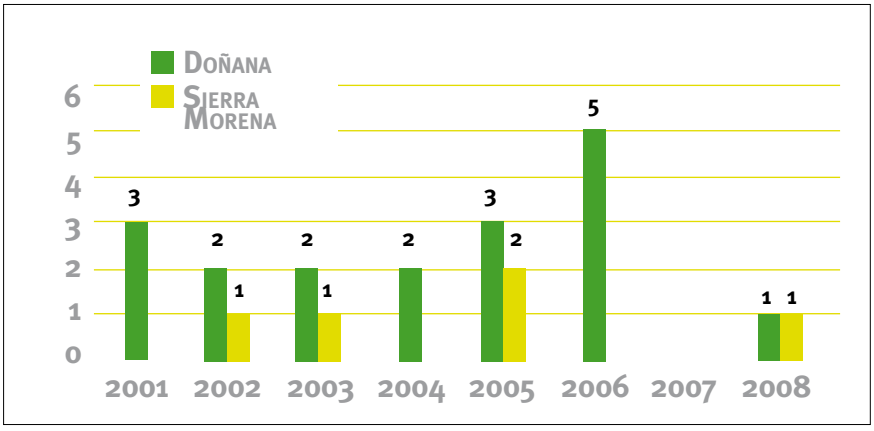

Figure 8. Road mortality in the Iberian lynx populations between 2001 and 2008. Dark green bars represents the Doñana population and light green bars the Sierra Morena population.

Figura 8. Mortalidad en carretera en las poblaciones de lince ibérico entre 2001 y 2008. Las barras verdes oscuras representan a la población de Doñana y las verdes claras a la población de Sierra Morena.

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; López et al., this book; Meli et al., this book).

• **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; Martínez et al., this book). Control of illegal hunting methods has helped decrease the number of leghold traps and snares to almost cero. In 2008, the epidemiological surveillance programme 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 programme is also working effectively. Thanks to this programme, which is led by staff of the Andalusian Government, the *Ex situ* Conservation Programme 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; López et al., this book; Meli et al., this book).

• **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.lifelince.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 Guadalmellato 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 and demographic 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 (see López et al., 2009). *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 (for details see text box by Ruiz et al., in Palomares, this book). The introduction of Sierra Morena genes into the Doñana population is considered essential for the long–term genetic health of this wild population (Godoy et al., this book). 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 place 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 Programme (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

Photo: Andoni Candela

for the captive breeding programme, 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, unpub. 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–Cardeña 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

Photo: Miguel Ángel Simón

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 (see Calzada et al., this book). 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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When despair grows in me
and I wake in the middle of the night at the least sound
in fear of what my life and my children's lives may be,
I go and lie down where the wood drake
rests in his beauty on the water,
and the great heron feeds.
I come into the peace of wild things
who do not tax their lives with forethought of grief.
I come into the presence of still water.
And I feel above me the day-blind stars
waiting for their light. For a time
I rest in the grace of the world, and am free.

The Peace of Wild Things, Wendell Berry

Photo: Héctor Garrido

Interdisciplinary methods in the Iberian Lynx *(Lynx pardinus)* Conservation Breeding Programme

Métodos multidisciplinares en el Programa de Cría para la Conservación del Lince Ibérico

Astrid Vargas, Iñigo Sánchez, Fernando Martínez, Antonio Rivas, José Antonio Godoy, Eduardo Roldan, Miguel Ángel Simón, Rodrigo Serra, Mª José Pérez, Alexander Sliwa, Miguel Delibes, Miguel Aymerich and Urs Breitenmoser

Resumen

El Programa de Cría para la Conservación del Lince Ibérico se plantea bajo un enfoque multidisciplinar, integrado en la Estrategia Nacional para la Conservación del Lince Ibérico, y desarrollado en colaboración con instituciones regionales, nacionales e internacionales. Las metas principales del Programa de Conservación *Ex situ* son: 1) mantener una población cautiva sana y gestionada genética y demográficamente; 2) crear nuevas poblaciones naturales de lince ibérico *(Lynx pardinus)* mediante la reintroducción de la especie. Con el fin de lograr el primer objetivo, el Programa tiene como cometido mantener el 85% de la diversidad genética actualmente existente en la naturaleza durante los próximos 30 años, lo cual requiere el manejo de 60 ejemplares reproductores (30 machos, 30 hembras). Las proyecciones de crecimiento indican que el Programa *Ex situ* debería alcanzar su meta poblacional para el año 2010 y que una vez logrado este primer paso, podrá dar comienzo la reintroducción de ejemplares nacidos en cautividad. El Programa se encuentra actualmente por delante de las proyecciones, habiendo alcanzado su objetivo poblacional en el año 2009, aunque la primera reintroducción de ejemplares de lince nacidos en cautividad sigue programada para el año 2010. Hasta la fecha, el trabajo actual del Programa *Ex situ* se ha centrado en la cría y mantenimiento de ejemplares sanos, tanto desde un punto de vista fisiológico como etológico, para lo cual se han utilizado técnicas de manejo y de investigación siguiendo un enfoque multidisciplinar, es decir, integrando conocimientos generados a partir de los campos de la biología, etología, nutrición, veterinaria, genética, fisiología,

endocrinología y ecología de la especie. Hemos considerado particularmente importante el adaptar nuestros métodos de manejo para ayudar a fomentar los comportamientos naturales del lince (caza, territorialidad, interacciones sociales) y ofrecer así un entorno cautivo que minimice el estrés y favorezca la reproducción natural. El presente capítulo tiene como objetivo ofrecer una visión global sobre cómo los conocimientos científicos aportados a través diversas disciplinas han sido esenciales para el diseño y desarrollo del Programa de Cría del Lince Ibérico. El capítulo se divide en 6 secciones (Manejo genético y demográfico, Etología y Manejo de la población cautiva, Aspectos Sanitarios, Fisiología Reproductiva, Reintroducción, Divulgación/Capacitación) y presenta, a modo de resumen, la información y los resultados contenidos en aquellos capítulos de este libro que tratan sobre la conservación del lince ibérico.

Palabras clave
Genética, manejo, etología, fisiología reproductiva, medicina veterinaria, reintroducción

Abstract
The Iberian Lynx Conservation Breeding Programme follows a multidisciplinary approach, integrated within the National Strategy for the Conservation of the Iberian Lynx, which is carried out in cooperation with national, regional, and international institutions. The main goals of the *Ex situ* Conservation Programme are to: 1) maintain a genetically and demographically-managed captive population; 2) create new Iberian Lynx *(Lynx pardinus)* free-ranging populations through reintroduction. To achieve the first goal, the Programme aims at maintaining 85% of the genetic diversity presently found in the wild for the next 30 years. This requires managing 60 (30 males, 30 females) Iberian lynx as breeding stock. Growth projections indicate that the *Ex situ* Programme should achieve such population target by the year 2010 and, once this goal is reached, reintroduction efforts could begin. The Programme actually surpassed this population target in 2009, although the first reintroduction of captive-born Iberian lynxes is still scheduled for 2010. To date, *ex situ* efforts have focused on producing physiologically and behaviourally sound captive-born individuals. To achieve this goal, we have used management and research techniques that rely on multidisciplinary input and knowledge generated on the specie's life history, behaviour, nutrition, husbandry, genetics, veterinary science, physiology, endocrinology and ecology. Particularly important has been adapting our husbandry schemes based on research data to promote natural behaviours in captivity (hunting, territoriality, social interactions) and a stress-free environment that is conducive to natural reproduction. The aim of this chapter is to provide an overview of how scientific knowledge from various disciplines is proving essential to shape management efforts within the Iberian Lynx Breeding Programme. The chapter is divided into 6 sections: Genetic and Demographic Management, Captive Husbandry and Behavior, Health and Veterinary Aspects, Reproductive Physiology, Reintroduction, & Outreach/Capacity Building, and it summarizes information and results contained in various chapters of this book as they relate to Iberian lynx conservation efforts.

Keywords
Genetics, husbandry, behaviour, reproductive physiology, veterinary medicine, reintroduction

Interdisciplinary methods in the Iberian Lynx *(Lynx pardinus)* Conservation Breeding Programme

Astrid Vargas, Iñigo Sánchez, Fernando Martínez, Antonio Rivas, José Antonio Godoy, Eduardo Roldan, Miguel Angel Simón, Rodrigo Serra, Mª José Pérez, Alexander Sliwa, Miguel Delibes, Miguel Aymerich and Urs Breitenmoser

Introduction

Owing to the precarious situation of the Iberian lynx *(Lynx pardinus)*, in the wild (Calzada et al., this book; Simón et al., this book), conservation measures need to be implemented effectively and efficiently, integrating efforts and working tools. Iberian lynx conservation could be conceived as a puzzle whose pieces should fit together adequately. One of such pieces involves *ex situ* conservation, which includes –among other activities– captive breeding, genetic and demographic management of the captive population, management of a Biological Resources Bank (BRB), preparing captive-born animals for release, as well as capacity building, education, and outreach efforts (Vargas et al., 2005b).

Current Iberian lynx conservation breeding efforts focus on producing physiologically and behaviourally sound captive-born individuals (Figure 1) that are suitable for future reintroduction efforts. For this purpose, we use management and research techniques that rely on multidisciplinary input generated on the specie's life history, behaviour, nutrition, veterinary and health aspects, genetics, reproductive physiology, endocrinology and ecology. The Programme stresses the importance of adapting our husbandry schemes based on research data to promote natural behaviours in captivity (hunting, territoriality, social interactions) and a stress-free environment that is conducive to natural reproduction. Some relevant research areas include: determining fecal hormone profiles for adult and subadult lynx (Pelican et al., this book; Dehnhardt et al., this book) studying reproductive behaviour and cub development (Antonevich et al., this book), determining reproductive health of male and female breeders (Roldan et al., this book; Göritz et al., this book), developing a non-invasive pregnancy test (Jewgenow et al., this book), establishing sound bio-security and biomedical protocols (Martínez et al., this book), establishing reference values for blood parameters (Pastor et al., this book; García et al., this book), genotyping all founders and making paring recommendations based on genetic distance between breeders (Godoy et al., this book; Leus and Lacy, this book). Within this scheme, one of our goals is to minimize the use of potentially invasive methods while simultaneously enhancing the trust between the animals and their keepers to assist in securing information on animal weight and gestational status. Between 2005 and 2008, a total of fifteen pregnancies resulted in the birth of 31 live offspring, of which 24 survive to date (Vargas et al., 2008 a; Figure 2). While describing various organizational aspects of the Iberian Lynx Conservation Breeding Programme, this chapter will present an overview of the information contained in various chapters of this book while emphasizing how results from multidisciplinary life science research can be integrated into an adaptive management approach to help recover the world's most endangered felid species.

The Iberian Lynx *Ex situ* Conservation Programme

The Iberian Lynx *Ex situ* Conservation Programme is integrated within the National Strategy for the Conservation of the Iberian Lynx, officially endorsed by the Spanish National Commission for the Protection of Nature (MARM, 2008; Calzada et al., this book). National, regional and international institutions collaborate with the Programme, which is currently implemented through a "multilateral commission" that includes the central governments of Spain and Portugal, together with the autonomous governments of Andalusia, Extremadura and Castille-La Mancha, Spain. Portugal, where no Iberian lynx populations were detected during the last 2002–2003 census, has developed its own *ex situ* conservation action plan in coordination with the Spanish Programme (Serra et al., 2005) and it is presently building a captive breeding facility while beginning to work on improving habitat for future re-establishment of lynx populations (Sarmento et al., this book).

Photo: Antonio Rivas

Figure 1. Iberian lynx female with her three-week-old captive-born cubs. Mothers tend to maintain their litter in the den for approximately one month and, afterwards, they frequently move their cubs to a different den. Generally, cubs begin to explore their immediate environment during their fifth week of life.

Figura 1. Hembra de lince ibérico con sus cachorros de tres semanas nacidos en cautividad. Las madres tienden a mantener la camada en su paridera natal durante el primer mes de vida y después suelen mover los cachorros a otra paridera. Generalmente, los cachorros comienzan a explorar su entorno más inmediato durante su quinta semana de vida.

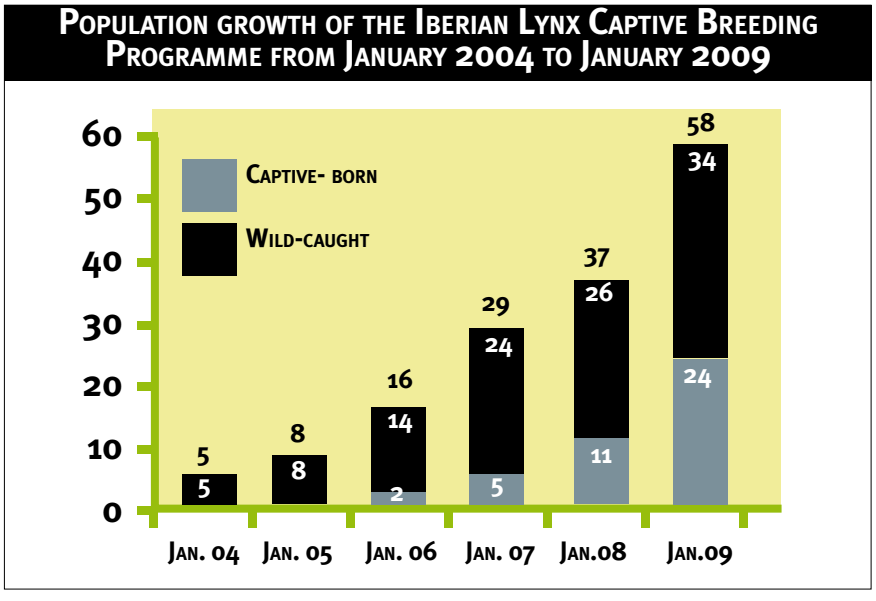

Figure 2. Population growth of the Iberian Lynx Captive Breeding Programme from January 2004 to January 2009 (Grey bars = captive-born cubs; black bars = wild-caught individuals).
Note: Between March and April, 2009, 18 new cubs have been born in the Breeding Programme, bringing up to 42 the number of Iberian lynx cubs raised in captivity to date.

Figura 2. Crecimiento poblacional del Programa de Cría del Lince Ibérico entre enero de 2004 y enero de 2009 (barras grises = cachorros nacidos en cautividad; barras negras = ejemplares provenientes de la naturaleza).
Nota: Entre marzo y abril de 2009, han nacido 18 nuevos cachorros en el Programa de Cría, elevando a 42 el total de cachorros de lince ibérico criados en cautividad.

The route map of the *Ex situ* Programme is the Iberian Lynx Captive Breeding Action Plan, an adaptive management document reviewed annually by an advisory captive breeding committee. The Plan's most recent update, which emphasizes habitat conservation using *ex situ* efforts as a working tool, has been recently endorsed by the highest Spanish authorities at the Sectorial Conference, in May 2008 (Vargas et al., 2008b). The main *Ex situ* Programme goals are twofold: 1) To maintain a genetically and demographically managed captive population that serves as a "safety net" for the species and 2) To help establish new Iberian lynx free-ranging populations through reintroduction programmes. To accomplish these goals, the Iberian Lynx Conservation Breeding Programme encompasses management and applied research strategies in the following six areas.

Genetic and demographic management of the captive population

Iberian lynx genetic goals for the *Ex situ* Programme were established based on recommendations provided by the IUCN/SSC Conservation Breeding Specialist Group in collaboration with the Iberian lynx *in situ* conservation managers. Population modelling using the Programme PM2000 (2004) revealed that it would be impossible to maintain 90% of existing gene diversity for 100 years because the wild population could not withstand extraction of the required 12 founders per year for 5 years (Lacy and Vargas, 2004; Leus and Lacy, this book). At the time of this first analysis in Spring 2004 there were six wild-caught lynxes already at El Acebuche captive breeding center, a facility that was constructed in 1991 in Doñana National Park, Southeastern Spain. At the same time, modelling suggested the feasibility of maintaining 85% of the existing genetic diversity for the next 30 years. The outcome eventually would be the *ex situ* management of 60 individuals (30 males, 30 females) as breeding stock (Lacy and Vargas, 2004; Godoy et al., this book; Leus and Lacy, this book). This goal could be attained by adding four founders (mostly cubs or juveniles) per year for 5 years as well as one extra founder every 2 years (from the handicapped lynxes that normally enter rescue centres) for the entire duration of the Programme. This level of extraction rate would have a minor impact on the viability of the wild populations according to the model designed by Palomares et al.,(2002). Following this scheme, the Programme could achieve its population target of 60 individuals by 2009 and reintroduction of captive-raised lynxes could begin in 2010, provided that adequate habitat was prepared. Originally, modelling predicted the availability of 12 to 13 captive-born lynxes annually from 2011 through 2019 (Lacy and Vargas, 2004). A recent update of the projections, using data from actual captive reproduction over the past 5 years, indicates that the annual number of animals available for release every year will oscillate between 20 and 40 Iberian lynxes (Godoy et al., this book).

During the past seven years (from Spring 2002 to 2008), the Andalusian government has extracted 26 wild-born Iberian lynxes for the Captive Breeding Programme; in addition, 10 more lynxes were brought into captivity because they had problems that compromised their survival in the wild (Simón et al., this book), although not all of these lynxes can be considered as potential founders of the captive population. The year 2008 marked the end of the planned extractions of wild lynxes for incorporation into the breeding population; still, those found injured or handicapped –with compromised probabilities of survival in the wild– will continue to trickle into the Breeding Programme. At the time of writing this chapter, there are 58 lynxes in the Programme (Figure 2), of which 42 (28 founders and 14 captive-born) and 6 (all founders) have pure Sierra Morena and Doñana ancestry, respectively. Ten of the captive-born cubs in captivity descend from crossings between Doñana and Sierra Morena founders (Figure 3). Thus, the Programme is presently ahead of growth projections (Godoy et al., this book) and could already begin to provide captive-born individuals for reintroduction efforts.

To provide the captive space needed to achieve the Programme's genetic goals, construction of two new Iberian lynx breeding centers –Granadilla (Extremadura) y Odelouca (Silves, Portugal)– is underway. An additional center in Cabañeros (Castille-La Mancha) is also scheduled for future construction. All breeding centers are strategically placed so they can be co-managed by administrations that commit to habitat preparation for future reintroductions. Breeding centers will function as a network, following EEP standards, each managing approximately eight Iberian lynx breeding pairs. All centers considered, the captive population will be managed as a metapopulation, a genetic counterpart to the Sierra Morena and Doñana free-ranging populations (Godoy et al., this book). Construction of breeding centers is tightly linked –via Memorandums of Understanding– to a regional compromise to prepare habitat for future reintroduction efforts. In this fashion, *in situ* and *ex situ* efforts work together towards a common goal.

Photo: Antonio Rivas

Figure 3. Mating between a male from Sierra Morena and a female from Doñana. Between 2005 and 2008, out of the 24 captive-raised cubs, ten were of mixed-origin "Doñana x Sierra Morena".

Figura 3. Apareamiento entre un macho de Sierra Morena y una hembra de Doñana. De los 24 cachorros criados en cautividad entre 2005 y 2008, 10 han sido de origen mixto "Doñana x Sierra Morena"

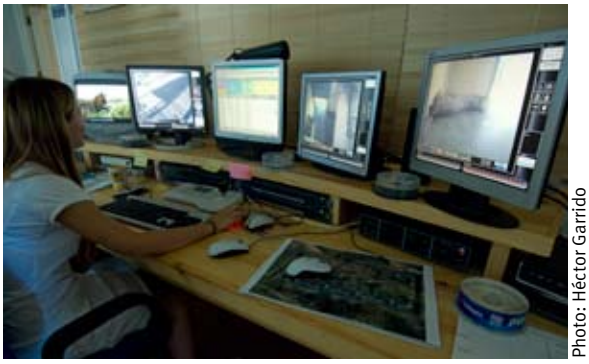

Photo: Héctor Garrido

Figure 4. Round-the-clock video-surveillance system. This system allows for early detection of potential problems while it permits studying the lynxe's behaviour without disturbing the animals. Thanks to this system, we have been able to detect seven abandoned cubs (all by primiparous mothers) and 18 sibling fights, thus allowing the team to react in time and save several Iberian lynx lives.

Figura 4. Sistema de videovigilancia (24-horas al día). Este sistema permite la detección temprana de cualquier problema potencial y favorece el estudio del comportamiento de los linces sin causarle molestias de ningún tipo. Gracias a este sistema se ha podido detectar el abandono de varios cachorros (todos por parte de madres primerizas) y diversas peleas entre hermanos n=18, permitiendo reaccionar a tiempo y salvar la vida de varios ejemplares de esta especie.

Table 1.

Table 1. Mating, gestation, parturition and cubs weaned (3-months-of age) of captive Iberian lynx between 2005 and 2008. The gestation period is measured as the time elapsed between the first observed mating and the delivery of the first offspring, while "labour" is measured from the first observed contraction to the delivery of the last young. ("m.f.unk"= male, female, unknown; NP= Non pregnant; N/A = Not applicable; *= whelping before due time; **=one hand-raised cub; *=all cubs hand-raised).**

Tabla 1. Apareamientos, gestaciones, partos y cachorros destetados (3 meses de edad) en el Programa de Conservación *Ex situ* del Lince Ibérico entre 2005 y 2008. El periodo de gestación se mide como el tiempo transcurrido desde la primera cópula observada hasta el nacimiento del primer cachorro, mientras que el trabajo del parto ("labour") se mide como el tiempo transcurrido desde la primera contracción observada hasta el nacimiento del último cachorro. ("m.f.unk"= macho, hembra, desconocido; NP = No gestante; N/A=No aplicable; * nacimiento antes de término; **=un cachorro criado a mano; ***todos los cachorros criados a mano)

Year	Female	Male	Date 1st mating	Number of matings	Gestation (days)	Labour	Cubs Born Total(m.f.unk)	Cubs Weaned Total(m.f.unk)
2005	*Saliega*	*Garfio*	23/01/2005	>5 (unk)	64	?	3(1.2)	2 (1.1)
2006		*Garfio*	19/01/2006	43	63	?	2(0.2)	2 (0.2)
2007		*Jub*	18/01/2007	43	64	1 h	2(1.1)	2(1.1)
2008		*Jub*	18/01/2008	65	64	32'	3(1.2)	2(1.1)
2005	*Aura*	*Jub*	28/01/2005	25	NP	N/A	N/A	N/A
2006		*Garfio*	30/01/2006	26	NP	N/A	N/A	N/A
2007		*Garfio*	15/01/2007	21	65	6 h	3(2.1)	3(2.1)
2008		*Garfio*	07/02/2008	21	65	5h 55'	2(1.1)	2(1.1)
2005	*Esperanza*	*Garfio*	11/02/2005	20	NP	N/A	N/A	N/A
2006		*Jub*	09/02/2006	25	65	>6h	2(1.1)	1(0.1)**
2007		*Jub*	03/01/2007	24	66	4h 40'	2(1.1)	1(1.0)
2008		*Jub*	06/02/2008	33	66	2h 43'	1(0.1)	1(0.1)
2006	*Aliaga*	*Cromo*	15/02/2006	13	56 *	50´	2(2.0)	0
2007		*Cromo*	22/01/2007	23	NP	N/A	N/A	N/A
2008		*Cromo*	07/02/2008	33	64	5h 22'	3(0.3)	3(0.3)***
2006	*Adelfa*	*Cromo*	19/01/2006	19	NP	N/A	N/A	N/A
2007		*Cromo*	27/01/2007	33	61 *	1 h	3(2.0.1)	0
2008		*Garfio*	01/02/2008	32	63	3h 25'	2(2.0)	2(2.0)
2007	*Artemisa*	*Almoradux*	02/01/2007	23	42 *	N/A	2(2.0)	0
2007	*Brisa*	*Arcex*	20/01/2007	15	NP	N/A	N/A	N/A
2008	*Brisa*	*Arcex*	19/01/2008	25	59 *	9h	2(0.1.1)	1(0.1)***
2008	*Boj*	*Arcex*	02/02/2008	31	65	6h	3(2.1)	2(0.2)***

Captive husbandry and behaviour

Captive husbandry is based on interdisciplinary input from a variety of animal-care fields, such as nutrition, behaviour, genetics, physiology and veterinary medicine, together with the systematic use of the scientific method. One of the Programme's key husbandry challenges is to strike a balance between fostering natural behaviours in captivity (hunting, territoriality, social interactions, etc.) and creating a stress-free environment where animals are more prone to mate. For this reason, the Breeding Programme favours naturalistic enclosures and promotes natural behaviours via environmental enrichment (Manteca, this book; Martos, this book). In order to get important information about the animals (such as their body mass or determining whether or not the females are pregnant), certain training techniques are being used. Some of these include obtaining regular weights by having the lynx step on a measuring scale. Such techniques are designed to avoid using invasive methods, which would stress the animals, and they also serve as a way to strengthen the trust between the animals and their keepers. Special care is taken to avoid domestication of captive lynxes, although this becomes a greater challenge in the case of hand-reared, abandoned cubs (Rivas et al., this book).

Lynx behaviour and activity patterns are also being carefully observed by a round-the-clock video surveillance system (see description in Vargas, 2005a) (Figure 4), which provides a great deal of information on conducts that could not easily be learned through observations in the wild, such as the ontogeny of predatory behaviour or the dynamics of the weaning process (Figure 5). Among other things, we have learned that mating behaviour in the Iberian lynx follows a similar pattern as that of other felids (Figure 3) (Lanier and Dewsbury, 1976; Rodríguez-Llanes, 2006). Breeding season in captivity mostly takes place throughout January and February, with most births occurring in March and April, as it is the case in the wild (Palomares et al., 2005; Palomares et al., this book "a"). The actual mating period lasts between two and three days during which lynxes copulate an average of 28 times (range: 13-65; n=460 copulatory bouts in 21 pairs; Table 1). Gestation period, counted from the time of the first copulation, ranges from 63-66 days (n=12). All parturitions that have occurred before 61 gestational days (n=4) have resulted in the birth of either dead or weak and not completely developed young, which were considered premature. Although variation between individuals is very high, most females are very consistent regarding their own timing to enter estrous and regarding the number of days they are gravid (Table 1).

Labour during whelping (regarded as the time lapsed between the first visible contractions until the delivery of the last offspring) varies widely between females, with some of them delivering each young within 10-15 min intervals while others taking up to 9 hours between the delivery of each offspring (Table 1). Primiparous females have a higher rate of failure to raise their young than multiparous ones. Out of the eight females that have whelped at El Acebuche center, only two first-time mothers –*Saliega* and *Aura*– managed to nurse all their young until weaning age. Two other dams –*Esperanza* and *Boj*– kept only one of their cubs after whelping and abandoned the rest of the offspring in their first litter, while three other females –*Adelfa*, *Aliaga* and *Brisa*– miscarried one of their offspring and delivered the rest of the cubs prematurely during their first gestation. One female, *Artemisa*, miscarried two undeveloped fetuses at 42 gestational days. Our video-surveillance system permits early detection of problems, which has resulted in the rescue of 7 Iberian lynx cubs that were hand-raised after being abandoned by their first-time mothers (Figure 5) (Rivas et al., this book).

This non-intrusive surveillance system has also allowed us to identify the existence of a sensitive period when Iberian lynx cubs become highly competitive to the point of siblicide (Vargas et al., 2005 b; Antonevich et al., this book). Spontaneous aggression erupted at 44 days of age in the first Iberian lynx litter born in captivity. The largest cub (a female) in a litter of three was killed by a brother who delivered lethal bites to the larynx and skull. Agonistic behaviour has been observed in nine of eleven subsequent Iberian lynx litters of two or more cubs, with the most intensive fighting occurring around the end of the sixth and seventh post-natal weeks, respectively (Antonevich et al., this book). This same phenomenon has been observed in the Eurasian lynx by Russian scientists at the Tcherngolovka facility who recorded aggressive behaviour in 16 of 31 litters, with deaths occurring in four cases (Naidenko and Antonevich, this book). The authors indicate that the highest prevalence of agonistic behaviour in Eurasian lynx cubs occurred at 36 to 64 days of age, with the greatest frequency during the seventh post-natal week. Although siblicide in Iberian lynx has not been directly observed in nature, a 1-month-old cub was found in the wild in 2003 with severe injuries compatible with bites from another cub. It may also be relevant that free-ranging Iberian lynxes generally give birth to three cubs, but 70% of the females

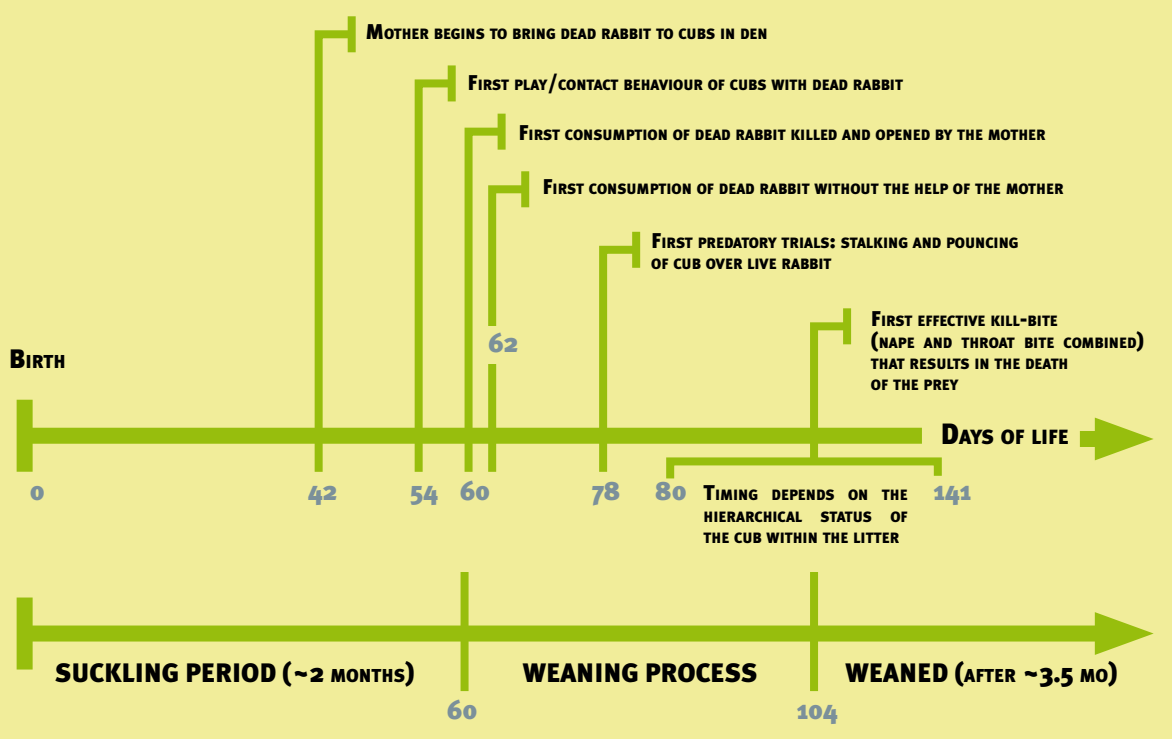

Figure 5. Developmental landmarks of predatory behaviour in mother-raised Iberian lynx cubs, coupled with timing of the lactation and weaning processes (n=9; adapted from Vázquez et al., 2007). During and after the weaning period, mothers play an active role in teaching their offspring how to hunt.

Figura 5. Hitos del desarrollo predatorio en cachorros de lince ibérico criados por sus madres y comparativa con la duración de los procesos de lactancia y destete (n=9; adaptado a partir de Vázquez et al., 2007). Durante y tras el proceso de destete, las madres juegan un papel activo en enseñar a cazar a sus crías.

are usually observed with only two young after approximately three months post-parturition (Palomares et al., 2005). Sibling aggression in Iberian lynx has influenced programme husbandry as staff must be vigilant and prepared to break up aggressive bouts during the sensitive period.

Health and veterinary aspects

The health considerations involved in captive breeding, reintroduction and translocation programmes are a source of great concern to conservation biologists, since captive-bred animals could potentially transmit infectious diseases to wild populations (e.g., tuberculosis in reintroduced Arabian oryx, Oryx leucoryx; Viggers et al., 1993) and vice-versa (e.g., wild-caught black-footed ferrets transmitted canine distemper to potentially uninfected, captive individuals; Williams et al., 1988). It is generally felt that most of these conservation programmes were lacking: 1) sufficient information on disease distribution and risk in captive populations; 2) sufficient information on disease incidence, distribution and risk in wild populations; 3) quarantine systems to prevent disease transmission; 4) a system to adequately track and detect pathogens.

Because relatively little was known about the diseases affecting the Iberian lynx, actions to improve our knowledge of the main diseases affecting the species was imperative. The Iberian Lynx Conservation Breeding Programme established a Veterinary Advisory Team (GAAS) dedicated to address diverse aspects of veterinary management and research, as well as protocol development (Martínez et al., 2006). To improve the understanding of the various diseases that could potentially affect the species, the Programme's main lines of action involve the establishment of preventive disease protocols for the captive population, capacity building of veterinary staff working with *in situ* and *ex situ* populations, and conducting research on general veterinary science (Martínez et al., this book).

Photo: José María Pérez de Ayala

Figure 6. Sometimes it is not easy to differentiate between play and fighting behaviours, especially because play-fighting is common in Iberian lynx cubs. In general, sibling fights do not occur during playful bouts.

Figura 6. A veces no es fácil diferenciar entre el comportamiento lúdico y el comportamiento agonístico, especialmente porque "jugar a pelearse" es frecuente en los cachorros de lince ibérico. Generalmente, las peleas entre hermanos de camadas no surgen durante el juego.

Research projects have helped determine the incidence and prevalence of infectious pathogens in captive and wild lynx populations (Millán, 2006; Meli et al., this book; López et al., this book), determination of normal vs pathological blood values (Pastor et al., this book; García et al., this book), and establishing parameters that point towards a potential renal disfunction in wild and captive lynxes (Jiménez et al., 2008; Jiménez et al., this book). The results of research, protocol development, and standardization efforts, coupled with dissemination and sharing of knowledge and experience among veterinarians working in the Programme are all contributing to more consistent diagnosis and treatment.

Reproductive physiology

Reproductive physiology studies and associated technologies increase the success rate of any captive-breeding programme and are important in helping with the conservation of wild felids in captivity (Wildt et al., 2009; Wildt et al., this book). Reproductive technologies are available for three major purposes: 1) assessing fertility and monitoring reproductive status; 2) assisting in breeding and maintenance of gene diversity; and 3) learning more about reproductive mechanisms of the endangered Iberian lynx.

Consistent with the need for more basic species information, our husbandry and breeding efforts have established/reconfirmed normative data on sexual maturity (males, 2-3 years; females, 2-3 years; Roldan et al., this book; Göritz et al., this book, respectively), oestrus length (3-7 days), copulations per pairing (28) and gestation interval (63-66 days) (Table 1). Faecal hormone monitoring has demonstrated that females experience ovarian cycles from January through May whereas males maintain testosterone year-round (Pelican et al., this book; Dehnhardt et al., this book). But species peculiarities also have been revealed, for example, oestrogen metabolite concentrations during pregnancy are significantly greater than in other felid species (Pelican et al., this book; Brown, this book). Additionally, progestin excretion profiles are unusually lengthy, largely because ovarian corpora lutea (sites of earlier ovulations) remain active much longer than in most other felids (Göritz et al., this book). Prolonged non-pregnant luteal activity has also been described in the closely related Eurasian lynx (*Lynx lynx*; Jewgenow et al., 2006; Dehnhardt, this book) and in the Canada lynx (Fanson et al., this book) suggesting an idiosyncratically-conserved mechanism for lynxes in general.

Regarding male reproductive physiology, sperm traits seen in the Iberian lynx are lower than those reported for some other felid species, yet higher than those reported for the Eurasian lynx and the bobcat (Gañán et al., in press; Roldan, et al., this book). It has also been found that thawed-out Iberian lynx spermatozoa are capable of

Photo: Antonio Rivas

Figure 7. Five-week-old Iberian lynx hand-raised cubs. Whenever possible, it is important to maintain hand-raised cubs in pairs/triplets. If this were not possible, it is recommendable not to maintain the cub in isolation but to provide a similar-size cub from a closely related species in order to promote adequate socialization and behavioural development.

Figura 7. Cachorros de lince ibérico de cinco semanas criados a biberón. Siempre que se pueda, es importante mantener a los cachorros criados a mano en parejas o en grupos de tres. Si esto no fuese posible, se recomienda no mantener al cachorro en aislamiento e intentar proporcionarle la compañía de algún cachorro de otra especie de felino de tamaño similar con el fin de promover una buena sociabilización y un desarrollo adecuado del comportamiento.

Photo: Antonio Rivas

fertilising viable in vitro matured domestic cat oocytes, thus opening up the possibility of examining functional capacity of spermatozoa from this species under laboratory conditions (Gañán et al., in press).

The *ex situ* population is also being used to explore a novel means of diagnosing pregnancy. Because all ovulating lynxes produce rising progesterone (regardless of conception), conventional hormone monitoring is not useful for identifying a gestating female (Pelican et al., this book). However, increasing concentrations of the hormone relaxin (in blood or urine) are indicative of pregnancy in felids (Van Dorsser et al., 2007). A unique non-invasive means of collecting blood has been developed using blood-sucking Triatomine bugs (*Rhodnius prolixus* or *Dipetalogaster maxima*) placed in specially-drilled hiding holes in the lynx's cork nestbox (Voigt et al., 2007; Jewgenow et al., this book). As much as 2 ml of blood can be extracted per bug, more than adequate for the assay. Urine is captured using special collection devices distributed throughout the animal's enclosure. Pregnant females express a positive relaxin signal from 32 to 56 days post-copulation of a 65-day gestation (Braun et al., 2009; Jewgenow, this book), thereby allowing managers to prepare for an impending parturition.

In order to assist breeding and maintaining genetic diversity, the Iberian Lynx *Ex situ* Programme collaborates with the maintenance of Biological Resources Banks (BRBs) for conservation of biomaterial gathered from wild and captive Iberian Lynx populations. Biomaterials are presently being safeguarded at two locations: the National Museum of

Ultrasonographical assessment of structure and function of the male and female reproductive organs in the Eurasian and the Iberian lynx

Evaluación ecográfica de la estructura y función de los órganos reproductivos masculinos y femeninos de linces boreales e ibéricos

Frank Göritz, Astrid Vargas, Fernando Martínez, Thomas B. Hildebrandt, Sergey V. Naidenko, Francisco Palomares, José Vicente López-Bao, Maria José Pérez, Miguel A. Quevedo and Katarina Jewgenow

Resumen

Con el fin de poder criar de modo eficiente al lince ibérico en cautividad, consideramos imprescindible conocer bien su biología reproductiva y disponer de métodos fiables para el seguimiento de su reproducción. Debido al número limitado de linces ibéricos, en el presente estudio se trabajó paralelamente con especies menos sensibles, como el lince boreal y el lince rojo. Se evaluaron distintos parámetros morfológicos y funcionales de los órganos reproductores masculinos antes, durante y después de la época de reproducción de linces boreales adultos en cautividad (n=3). El tamaño y la morfología del tracto reproductivo fueron estudiados mediante ecografía transcutánea (testículos) y transrectal (glándulas sexuales auxiliares). En el caso del lince ibérico, se trabajó con varios machos del Programa de Cría en Cautividad (n=7; 4 adultos y 3 juveniles), así como con ejemplares de las poblaciones de vida libre (n=4 adultos); todas las ecografías se realizaron en época no reproductiva (finales de noviembre/principios de diciembre). Los testículos y la próstata del lince boreal mostraron cambios de tamaño y de textura relacionados con la época del año. Los volúmenes testiculares máximo y mínimo fueron 2,8 ± 0,76 cm^3 y 1.5 ± 0,3 cm^3 (Media ± EE), respectivamente. Se observaron las concentraciones más elevadas de testosterona en febrero (1240 ± 393 ng/g heces) con un segundo incremento en mayo (971 ± 202 ng/g heces). Las concentraciones más bajas de testosterona se detectaron en enero (481 ± 52.9 ng/g heces). En el lince ibérico, el volumen testicular medio osciló entre 0,4 y 2,0 ± 0,2 cm^3 en juveniles y adultos, respectivamente. La concentración media de testosterona en sangre fue más alta en el lince ibérico (0,32 ± 0,07 ng/ml) que en el lince boreal (0,16 ± 0,04 ng/ml). En las hembras de lince boreal e ibérico, así como en las de lince

Photo: Luis D. Klink

rojo, se utilizó la ecografía transrectal para visualizar las estructuras ováricas (folículos, cuerpos lúteos) y para evaluar la actividad ovárica. Además, se realizaron análisis de progesterona y estradiol en sangre. La presencia de cuerpos lúteos activos durante la época no reproductiva fue confirmada mediante ecografía y también mediante análisis hormonal, denotando unos niveles elevados de progesterona en sangre: una media de 3,56 ± 1,3 ng/ml en las hembras de lince boreal y de 6,1 ± 0,26 ng/ml en las de lince ibérico. Los resultados ecográficos de la estructura ovárica indican que los cuerpos lúteos formados a partir de la ovulación permanecen activos hasta noviembre y regresionan antes del inicio del siguiente estro.

Palabras clave
Ecografía, estacionalidad, evaluación reproductiva, calidad espermática

Abstract
Knowledge on lynx reproduction biology and reliable methods for reproductive monitoring are imperative to assist and propagate the Iberian lynx in captivity. Because of limited access to Iberian lynxes the less endangered Eurasian lynx and the bobcat were included as a surrogate species in this comparative study. We examined morphological and functional parameters of the male reproductive organs prior to, during and after the breeding season in adult captive Eurasian lynxes (n=3). Size and morphology of the reproductive tract was monitored by transcutaneous (testes) and transrectal (accessory sex glands) ultrasonography. Captive (n=7; 4 adult and 3 juvenile animals) and free ranging (n=4 adult animals) male Iberian lynxes were available for ultrasound examination out of breeding season (late November/early December). Testes and prostate of Eurasian lynx showed seasonal-related changes in size and texture. The maximum and minimum testicular volume was 2.8 ± 0.76 cm^3 and 1.5 ± 0.3 cm^3 (Mean ± SEM), respectively. The highest testosterone concentrations were found in February (1240 ± 393 ng/g feces). A second increase was documented in May (971 ± 202 ng/g feces). The lowest testosterone concentrations were measured in January (481 ± 52.9 ng/g feces). In the Iberian lynx the mean testicular volume ranged from 0.4 cm^3 in juvenile to 2.0 + 0.2 cm^3 in adult animals. Mean testosterone concentration measured in blood serum was higher in the Iberian lynx (0.32 ± 0.07 ng/ml) than in the Eurasian lynx (0.16 ± 0.04 ng/ml). In female Eurasian and Iberian lynxes and in bobcats, transrectal ultrasonography was implemented to visualize ovarian structures (follicles, corpora lutea) and to assess ovarian activity in addition to analysis of serum progesterone and estradiol. The presence of active corpora lutea during the non breeding season was confirmed by ultrasonography and by elevated serum levels of progesterone averaging 3.56 ± 1.3 ng/ml in Eurasian and 6.1 ± 0.26 ng/ml in Iberian lynx, respectively. The ultasonographical findings on the ovarian structure suggests strongly that corpora lutea developed after ovulation stay active at least until November and regress before the onset of the next estrus.

Keywords
Ultrasonography, seasonality, reproductive assessment, reproductive hormones, sperm quality

Ultrasonographical assessment of structure and function of the male and female reproductive organs in the Eurasian and the Iberian lynx

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Introduction

All species comprised within the genus Lynx: the Eurasian lynx *(Lynx lynx)*, the Canada lynx *(Lynx canadensis)*, the bobcat *(Lynx rufus)* and the Iberian lynx *(Lynx pardinus)* present similar reproductive parameters (Parker and Smith, 1983; Kvam, 1991; Hayssen et al., 1993; Dehnhard et al., this book). In recent studies on Eurasian lynx we have shown that male reproduction is seasonal corresponding to the female estrus (Jewgenow et al., 2006a). Fecal testosterone concentration, volume of ejaculates, percentages of motile spermatozoa and intact sperm were maximized during the breeding season in February/March (Göritz et al., 2006b; Dehnhard et al., this book). In several felid species, pregnancy diagnosis based on faecal hormone metabolites became almost a routine procedure. However, it has been shown that progesterone metabolites in lynxes did not follow the typical pregnancy pattern and made pregnancy diagnosis unattainable by faecal sampling (Jewgenow et al., 2006b; Pelican et al., 2006) as well as by urinary progesterone (Dehnhard et al., 2008; Jewgenow et al., this book). Surprisingly, progesterone measurement suggestive of luteal activity was also detected after the weaning of cubs (Göritz et al., 2009). This does not occur in domestic cats (Tsutsui and Stabenfeldt, 1993).

Because information on reproductive physiology in lynxes is limited, our recent studies focused on implementation of transrectal ultrasonography to assess their reproductive health and to monitor ovarian and testicular activity of the two sister taxa: the Iberian and Eurasian lynx. Due to limited access to the endangered Iberian lynx, where frequent examinations were not possible, Eurasian lynx and bobcats were also examined for comparative purposes.

Material and methods

Animals

Iberian lynxes (IL) in captivity were managed under the Iberian Lynx *Ex situ* Conservation Programme and housed at three different locations in Southern Spain (El Acebuche Captive Breeding Center in Doñana National Park, Huelva; Jerez Zoo, Cádiz, and La Olivilla Captive Breeding center, in Jaén) (Vargas et al., this book). Almost all females from the breeding centers were examined in late October 2006 (n=10) and late November 2007 (n=18). Captive males (n=4) were examined in November 2005 and 2006. Additionally, seven males and six females captured from the free ranging populations in Doñana National Park were also examined to assess their health and reproductive status in late November/early December 2006. Eurasian lynxes (EL) were kept in a field research station situated 50 km northeast of Moscow, surrounded by the natural vegetation of the Russian South Taiga forests (Naidenko et al., this book). Eurasian females were examined in June 2002/2005 (n=11), July (n=7) and November 2003 (n=3). In addition, males were examined prior to (November), during (March) and after

(April and June) breeding season between 2002 and 2004. Examined bobcats (BC) were kept in Russia at the same station (n=1 female, June 2007) and at the Jerez Zoo in Spain (n=3 females, November 2007). All females were kept in separate enclosures. During the breeding season adult females were allowed to mate. Mating was observed, either by direct observation (in Russia) or by 24 hours surveillance using remote controlled camera systems (in Spain). For data evaluation, the females were grouped according to there different age and breeding status: (i) juvenile (<2 years); (ii) adult (>2 years), no mating; (iii) adult, mating, no birth (pseudopregnant); and (iv) adult, mating, birth.

Ultrasonography

Eurasian lynxes were immobilized by IM administration (via blow pipe) of 3.5 to 4.0 mg/kg xylazine hydrochloride (Rompun™ 10%; Bayer, Leverkusen, Germany) and 3.0 to 3.5 mg/kg ketamine hydrochloride (Ketamine 10%™; Essex, Munich, Germany). In the Iberian lynxes and bobcats we used 50 µg/kg medetomidine (Domitor™, Pfizer, Karlsruhe, Germany) and 5 mg/kg ketamine hydrochloride (Imalgene 1000™). After examination and sample collection, anaesthesia was reversed with 0.2 mg/kg atipamezol hydrochloride (Antisedan™; Pfizer, Karlsruhe, Germany). The entire genital tract of each female was examined from caudad to craniad by transrectal ultrasonography in lateral recumbency (Göritz et al., 1997; Hildebrandt et al., 2000). A real-time, B-mode ultrasound scanning system (CS 9100 Oculus, Picker International GmbH, Espelkamp, Germany) equipped with a 7.5 MHz curved linear transducer (EUP-F 334) was used. The transducer was fitted with of two specific adaptors (15 and 25 cm in lengths, A. Schnorrenberg Chirurgiemechanik, Schönwalde, Germany) and introduced into the rectum using ultrasound gel. The dimensions of the ovaries were measured using a calliper system integrated into the ultrasound machine and their volume calculated as that of a simple spheroid (Göritz et al., 2003). Corpora lutea (Cll) were counted. The diameter of the smallest and largest corpus luteum (Cl) was measured and the mean volume of total luteal tissue (mm^3) calculated per animal ($V=4/3\ \pi$ * mean Cl radius^3 * number of Cll). For follicle counts, follicles were defined as anechoic structures >1 mm in diameter.

In males, ultrasonography of testes and accessory glands was performed as described before (Göritz et al., 2006b). Accessory glands (prostate) were visualized transrectally and the testes and epididymis by transcutaneous ultrasound using a handheld 7.5 MHz curved linear transducer. The dimensions of the accessory glands and testes were measured. The volume of the prostate and testes were calculated according to the volume of a simple rotation ellipsoid ($V=1/6\ \pi$ * length * height * width) accommodating the spherical and symmetrical shape of these organs.

Endocrinology

Blood samples were taken during each ultrasound investigation by venepuncture. Additionally, blood was collected using the same method during pregnancy from one BC (in June) and two EL (May). Serum was separated after centrifugation. Also, IL blood samples were obtained in March (n=14) non-invasively using blood-suckling bugs *(Dipetalogaster maxima)* as described and validated earlier (Voigt et al., 2004). The bugs were placed into cork plates, which were installed at the lynxe's preferable resting sites. The ingested blood was withdrawn from bugs and centrifuged (Braun et al., 2008; Jewgenow et al., this book).

The obtained serum (syringe collection during anesthesia) and plasma (bug ingested blood) samples were kept frozen until hormone assessment. Progesterone, estradiol (females) and testosterone (males) were measured in the blood serum or plasma by enzyme immunoassays with double antibody technique (Meyer et al., 1997) after extraction as described and validated before (Göritz et al., 1997; Dehnhard et al., 2008; Jewgenow et al., 2009; Dehnhard et al., this book).

Statistics

Data are presented as means ± standard errors of the mean (SEM). Comparisons of mean values were performed by Welch corrected unpaired t-Test, when the number of examinations or samples exceeded n=6. Relationship between volume of luteal tissue and progesterone concentration in blood serum was determined by Spearman correlation. All statistical tests were based on a 5% level of significance. The statistical procedures were performed with the software programme Instat Version 3 (Graphpad Software Inc.).

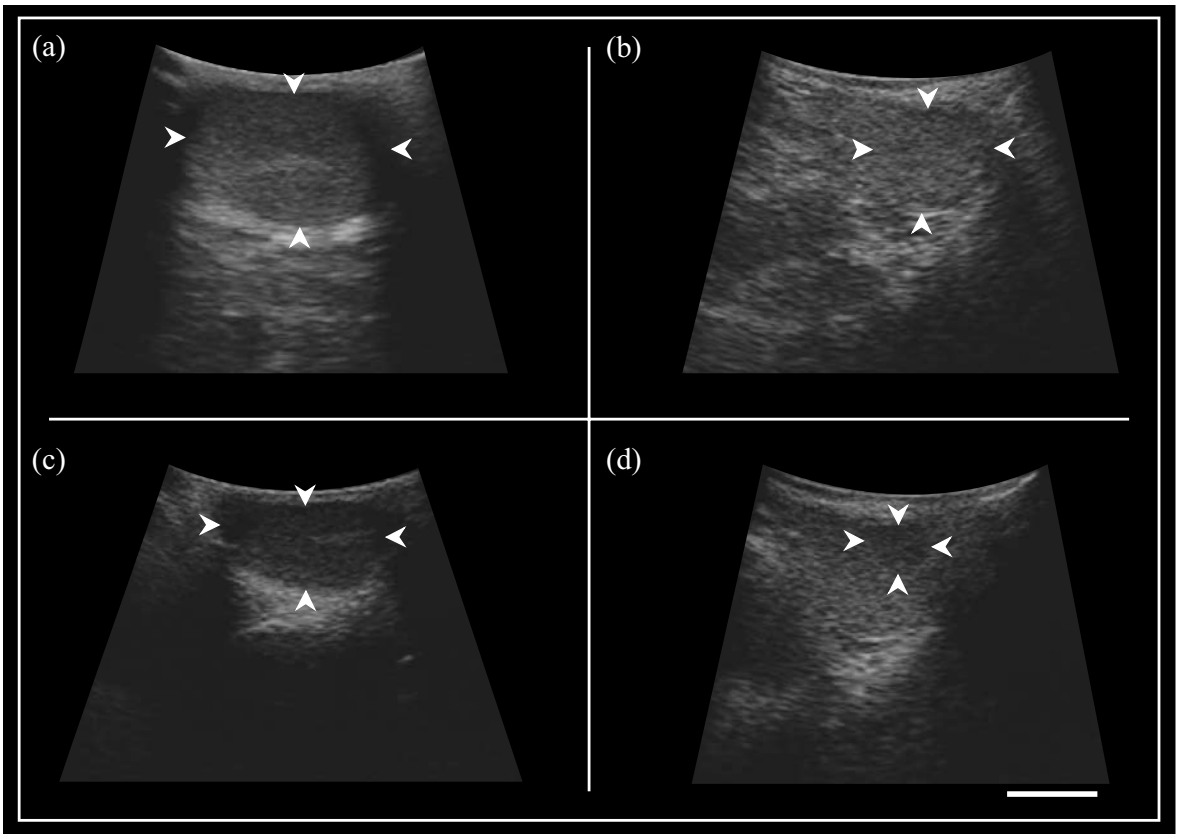

Figure 1. Sonograms of testis (a and c) and prostate (b and d) of a single male Eurasian lynx during the breeding season (March; a and b) and out of breeding season (November; c and d). Note distinct changes in size of the testis and prostate and texture of parenchyma. Arrow heads indicate organ borders. Scale bar represent 1 cm.

Figura 1. Ecografía de los testículos (a y c) y de la próstata (b y d) de un macho de lince euroasiático durante la época de reproducción (marzo; a y b) y fuera de ésta (noviembre; c y d). Obsérvense los cambios en el tamaño de los testículos y de la próstata así como en la textura del parénquima. Las cabezas de flecha indican los bordes de los órganos representados. La barra representa una escala de 1 cm.

Results and Discussion

Figure 1 and Figure 2 represent typical sonomorphology of urogenital tracts of male (Figure 1) and female (Figure 2) lynxes. In all lynx species, sonomorphology of urogenital tracts was similar to other carnivores (Göritz et al., 1997) and followed the typical, size-related structure of other felids (Göritz et al., 2005, 2006a). In male Eurasian lynx, seasonal fluctuation of male reproductive organs was evident. The testes and prostate showed changes in size and texture (Figure 1). They were most active in March and June, while in April and in November they appeared inactive. Seasonal changes were most pronounced in the testes, with a maximum and minimum volume of 2.8 ± 0.76 cm^3 and 1.5 ± 0.3 cm^3, respectively. Examination of the IL was not performed during the breeding season; therefore a seasonal pattern could not be shown. In the Iberian lynx the mean testicular volume ranged from 0.4 cm^3 in juvenile to 2.0 ± 0.2 cm^3 in adult animals. The volume of prostate ranged from 0.05 ± 0.02 to 0.2 ± 0.05 mm^3 in juvenile and adult animals, respectively.

The examination of female ovaries was of special interest; because luteal hormone activity was measurable not only during pregnancy, but also in mated non-pregnant females and in lactating females (Dehnhard et al., 2008; Jewgenow et al., in this book). By transrectal ultrasound, luteal activity after parturition was confirmed by detection of corpora lutea (Figure 2) and by elevated serum levels of progesterone (Table 1) in EL and IL, in June/July and November/December, respectively. These findings are in agreement with our recent results on steroid hormone metabolite concentrations measured in faeces and urine (Jewgenow et al., 2006b; Dehnhard et al., 2008; Dehnhard et al., this book; Jewgenow et al., this book). A typical faecal ovarian hormone profile

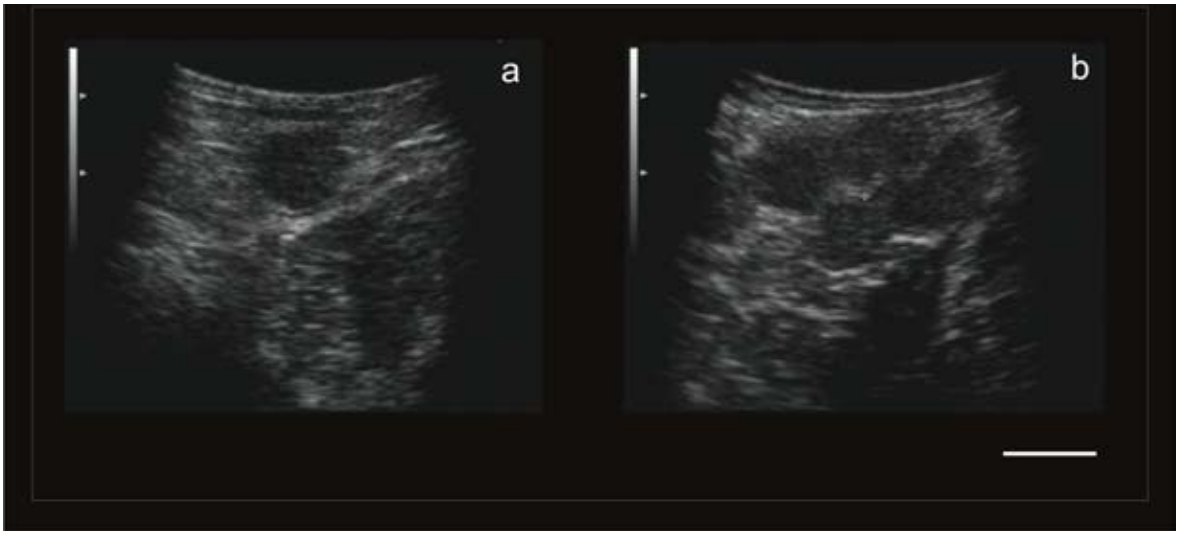

Figure 2. Sonograms of ovaries of two different adult Iberian lynxes out of breeding season in late November. The ovary of an animal in which no mating was observed during the breeding season appears inactive (a). The homogeneous parenchyma does not show any corpora lutea. The ovary of an animal in which mating, birth and lactation was observed (b) is characterised by multiple corpora lutea. They appear as spherical moderate echoic structures. Ovarian border and corpora lutea are indicated by arrowheads and numbers, respectively. The scale bar represents 1 cm.

Figura 2. Ecografía de los ovarios de dos hembras de lince ibérico fuera de la temporada de reproducción (a finales de noviembre). El ovario de una hembra que no se apareó aparece inactivo (a). El parénquima homogéneo no muestra ningún cuerpo lúteo. El ovario de un animal que se ha apareado, ha gestado y ha mostrado un periodo de lactación (b) se caracteriza por los múltiples cuerpos lúteos. Estos aparecen como estructuras esféricas moderadamente ecóicas. Los bordes del ovario y de los cuerpos lúteos aparecen indicados por cabezas de flecha y números respectivamente. La barra representan una escala de 1 cm.

in the Eurasian lynx included an absence of a significant estrogen or progesterone elevation before mating, a positive correlation between faecal progesterone and estradiol metabolites increases in both hormones during pregnancy, decreases towards parturition, and increases again during lactation period. To our knowledge, the existence of elevated progesterone during lactation and presumably active corpora lutea throughout much of the year is unique for felid species. A moderate serum progesterone concentration of about 5 ng/ml was measured out of breeding season in the present study (Table 1), although it was about four to 10 times higher during pregnancy (EL=61.1 ± 13.3 ng/ml; IL=17.0 ± 10.1 ng/ml; BC=28.4 ng/ml). The existence of large corpora lutea and increased volume of luteal tissue several months after parturition detected by ultrasound examination (Table 1) allows us to assume that progesterone is of luteal origin, although additional studies are required to confirm that the source is ovarian and not adrenal.

The low but steady progesterone concentration may function to induce a negative feed back to inactivate folliculogenesis. That would represent a mechanism to turn the normally polyoestric cycle seen in most felids into in a monoestric cycle in the lynx and thus contribute to the seasonality of its breeding pattern so as to match the seasonal sperm production in the males (Göritz et al., 2006b; Jewgenow et al., 2006b). It is known that long term application of exogenous progesterone derivates, frequently used in cats for contraception (Concannon and Lein, 1983; Concannon and Meyers-Wallen, 1991) suppress ovarian function, although they can also induce uterine pathology (Munson et al., 1993). The apparent correlation between estrogen and progesterone secretion suggested by current results may reflect the important role of estrogens, which might help maintain progesterone receptors and sensitivity for progesterone.

Juvenile animals presented small ovaries (mean ovarian volume in mm^3: 110.4 ± 70.5 in BC; 160.7 ± 91.3 in IL; 288.0 in EL) without corpora lutea and very low (<0.5 ng/ml) progesterone concentrations (Table 1). Adult lynxes without observed mating also had no corpora lutea (EL, BC) or only few (1.6) (IL), indicating that the most likely normal mechanism would be that of induced (reflex) ovulation. Whereas the EL may be an "obligate" induced ovulator, the IL seems able to ovulate without copulation in some instances. Mean number of corpora

Species	Age class (No. of animals)	Recent breeding history #	Mean (±SD) ovarian volume per animal [mm³]	Mean (±SD) No. of follicles per animal	Mean (±SD) No. of Cll and (cubs born) per animal	Mean (±SD) volume of luteal tissue [mm3] (No. of animals)	Mean (±SD) P4 [ng/mL] (No. of samples)	Mean (±SD) E2 [pg /mL] (No. of samples)
Bobcat	juvenile (n=1)		110.4 ± 70.5	0	0	0	0.4	0.1
	adult (n=2)	no mating	739.0	0	0	0	4.4 ± 2.5 (2)	1.7 ± 1.7 (2)
	adult (n=1)	mating, birth	2477.8 ± 2108	0	1.5 ± 0.7 (1.5 ± 0.7)	109.2 (1)	6.3	1.8
	adult (n=1)	pregnancy* (3th week, June)	n.d.	n.d.	n.d.	n.d.	28.4	1.15
European lynx	juvenile (n=1)		288	0	0	0	n.d.	n.d.
	adult (n=2)	no mating	1703.7 ± 1216.7	0	0	0	n.d.	n.d.
	adult (n=1)	mating, no birth	2843.8 ± 1637	2 ± 1.4	4 ± 1.4	1342.5 ± 286.6 (2)	3.9 ± 0.9 (2)	1.2 ± 0.1 (2)
	adult (n=17)	mating, birth	2315.8 ± 1131.1	0.5 ± 1.1	3.3 ± 0.8 (2.6 ± 1.2)	2067.3 ± 743.4 (8)	4.9 ± 2.3 (16)	0.8 ± 0.4 (10)
	adult (n=2)	pregnancy* (3th week, May)	n.d.	n.d.	n.d.	n.d.	61.1 ± 13.3 (2)	n.d.
Iberian lynx	juvenile (n=4)		160.7 ± 91.3	0	0	0	0.5 ± 1.0 a (15)	0.6 ± 0.6 (13)
	adult (n=3)	no mating	221.3 ± 167.7	0.3 ± 0.6	1.6	0	2.3 ± 0.2 (2)	n.d.
	adult (n=9)	mating, no birth	994.9 ± 929	0	3.8 ± 1.2 a	1082.0 ± 584.5 (6)	4.3 ± 2.1 b (9)	3.7 ± 6.4 (8)
	adult (n=19)	mating, birth	1319.7 ± 825.4	0.7 ± 0.5	5.3 ± 1.2 b (2.1 ± 0.3)	1441.8 ± 581.8 (14)	4.3 ± 1.4 b (19)	2.8 ± 3.5 (14)
	adult (n=14)	pregnancy* (3th-8th week, March)**	n.d	n.d.	n.d.	n.d.	17.0 ± 10.1 c (14)	n.d.

breeding history in the year of examination; no ultrasound examination was conducted during pregnancy
***** blood collection by venepuncture under general anaesthesia
****** non invasive blood collection with blood suckling bugs (Braun et al., 2008)
§ volume of luteal tissue calculated for each animal ($V=4/3\ \pi$* mean Cl radius³* No of Cll); Cl=corpus luteum, Cll=corpora lutea
n.d. not determined
a, b, c different superscript indicate significant differences between the means estimated by Welch unpaired t-test corrected

Table 1. Individual morphological and endocrinological parameters (Mean ± SD) describing the ovarian activity of the bobcat, the Eurasian and the Iberian lynx at the time of ultrasound examinations conducted out of breeding season (from June to November).

Tabla 1. Parámetros morfológicos y endocrinológicos (media y ± DE) que describen la actividad ovárica del lince rojo, del lince euroasiático y del lince ibérico durante las ecografías realizadas fuera de la época reproductora (de junio a noviembre).

lutea detected ultrasonographically after parturition was 3.3 and 5.3 in EL and IL, respectively (Table 1). While in the EL the number of corpora lutea was generally consistent with the number of cubs born, there were always more corpora lutea detected than cubs born in the IL (mean litter size in EL=2.6 and in IL=2.1, respectively). Whether this is caused by absence of fertilization of oocytes after ovulation or by early embryonic resorption or possibly by lutenization of antral follicles and subsequent development of accessory corpora lutea is yet uncertain. Further investigations are necessary to reveal this aspect of IL reproductive physiology.

Conclusions

Fundamental knowledge of basic reproductive physiology is essential to improve reproduction in captivity by assisted reproduction and gamete banking (Roldan et al., this book). Our comparative approach is very useful to gain new insights into the reproductive pecularities of both Eurasian and Iberian lynx. Since frequent examination procedures are not possible in the endangered Iberian lynx, the Eurasian lynx can serve as a model species. Assessment of reproductive health by transrectal ultrasound was applied to study seasonal changes in male and female Eurasian lynx. This knowledge was essential to assess the reproductive soundness and physiology of the Iberian lynx. The ultrasonographical findings strongly suggest that corpora lutea developed from ovulations in mid-winter and stayed active until at least late November. Their functional role on lynx reproduction is still unknown, but we hypothesize that the associated elevated progesterone may support lactation, prevent a new estrus cycle and thus restrict the breeding season to midwinter (as opposed to the strategy used by the

polyoestric bobcat). Further comparative longitudinal ultrasound and hormone evaluations on all species within the lynx family are needed to further elucidate their unique reproductive patterns.

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Photo: Antonio Rivas

It takes two days to learn everything about a man;
to know animals you will need more time.

Iranian Proverb

Photo: Luis Díez Klink

Pregnancy diagnosis in Iberian lynx *(Lynx pardinus)* based on urinary and blood plasma hormones

Diagnóstico de gestación en el lince ibérico *(Lynx pardinus)* basado en la presencia de hormonas en orina y plasma sanguíneo

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Fernando Martínez, Lourdes Anaya, Astrid Vargas and Martin Dehnhard

Resumen

El Programa de Conservación *Ex situ* del Lince Ibérico constituye una parte esencial de un Plan de Acción coordinado para conservar a este felino amenazado. Para llevar a cabo con éxito el Programa de Cría en Cautividad es necesario disponer de sistemas de diagnóstico de gestación fiables y no invasivos. Durante tres años de estudio, se tomaron muestras de orina de seis hembras de lince ibérico en cautividad (un ciclo sin gestación, un ciclo de pseudogestación y 11 ciclos de gestación). Se determinaron los niveles de progesterona y estradiol en extractos de orina y se caracterizaron los metabolitos relevantes de estrógenos en orina mediante HPLC. Además, se utilizó el test comercial Witness® Relaxin para detectar la presencia de la hormona relaxina en orina, así como en muestras de sangre obtenida mediante chinches hematófagos.

En el lince ibérico el perfil de la progesterona en orina no mostró el patrón habitual de aumento durante la gestación que se observa generalmente en otras especies de felinos. Sin embargo, sí se observó un incremento de estrógenos en orina, que aumentaron de 3.8 ± 0.6 a 8.6 ± 0.5 ng/mg creatinina ($P<0.001$) durante la gestación. Los niveles de estrógenos fueron más elevados en las hembras gestantes que en las que presentaban pseudogestación ($P<0.05$). En una hembra que no copuló no se observó ninguna diferencia en los niveles de estrógenos entre la estación reproductiva y la no reproductiva. Aunque el test Witness®Relaxin fue positivo en muestras de plasma obtenidas mediante chinches hematófagos a partir de hembras entre los 32 y 56 días de gestación, la prueba no funcionó en muestras de orina obtenidas durante el mismo intervalo de tiempo. Tras concentrar la orina por ultrafiltración (>50 x), se observó una leve reacción en el test Witness®Relaxin en muestras obtenidas entre los 29 y los 46 días de gestación. En muestras de orina concentrada obtenidas a partir de hembras no embarazadas y de hembras al inicio de la gestación los resultados de la relaxina fueron negativos. Sin embargo, se debe juzgar con precaución cualquier resultado negativo en la prueba de relaxina, dado que los niveles de esta hormona podrían situarse por debajo del umbral de detección del test.

Palabras clave

Relaxina, lince ibérico, diagnóstico de gestación, orina, suero, test Witness Relaxin®

Abstract
The Iberian lynx *Ex situ* Conservation Programme is an essential part of a coordinated Action Plan to conserve this endangered felid. Successful Captive Breeding demands reliable methods for monitoring reproduction, including reliable non-invasive pregnancy diagnosis. During a three year study, urine samples from six captive Iberian lynx females were obtained (1 non-pregnant, 1 pseudo-pregnant and 11 pregnant cycles). Progesterone and estradiol were determined in urinary extracts and relevant urinary estrogen metabolites were characterized by HPLC. Additionally, the Witness® Relaxin test was used to determine relaxin in urine samples and blood plasma collected by blood suckling bugs.
Urinary progesterone did not follow the typical pregnancy-related course of felids. In the Iberian lynx we failed to demonstrate a progesterone elevation during pregnancy. In contrast, urinary estrogens increase from 3.8±0.6 to 8.6±0.5 ng/mg creatinine ($P<0.001$) throughout the gestation period. A comparison of pseudo-pregnant with pregnant cycles revealed a further increase of estrogens caused by implantation ($P<0.05$). In one female that failed to mate, no difference was detected between estrogen levels during breeding and non-breeding season. Although the Witness®Relaxin test was positive in plasma samples collected from animals between days 32-56 of pregnancy, it failed to detect relaxin in urine samples collected from the same stage of pregnancy. A weak relaxin reaction in urine samples collected from animals between days 29-46 of pregnancy was detectable after urines were concentrated by ultrafiltration (>50 x). Concentrated samples obtained from non-pregnant and early pregnant animals yielded negative test results. In conclusion, urinary estrogens and the Witness® Relaxin test can be applied for pregnancy diagnosis in the Iberian lynx. For estrogens, serial sampling is necessary, so we recommend relaxin as the hormone of choice to detect pregnancy in the Iberian lynx, since a single positive signal already indicates the presence of a placenta and, thus, an ongoing gestation. A negative relaxin test, however, must be judged carefully because hormone levels might be below the detection level.

Keywords
Relaxin, Iberian lynx, pregnancy diagnosis, urine, serum, Witness® Relaxin test

Photo: José María Pérez de Ayala

Pregnancy diagnosis in Iberian lynx *(Lynx pardinus)* based on urinary and blood plasma hormones

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Introduction

The Iberian lynx *Ex situ* Conservation Programme is an essential part of a coordinated Action Plan to conserve this highly endangered species (Vargas et al., 2008). Besides ensuring the existence of the Iberian lynx in captivity, the *Ex situ* Programme has the benefit of allowing the study of various aspects of the specie's biology and physiology that could not easily be studied in the wild. One of such aspects is the understanding of reproductive physiology and the development of methods for non-invasive monitoring of the reproductive status (Braun et al., 2008; Dehnhard et al., 2008; Jewgenow et al., 2006; Dehnhardt et al., this book; Pelican et al., this book). Pregnancy diagnosis by monitoring ovarian physiology is of particular importance in this respect, particularly as a management tool for the Captive Breeding Programme. In lynx, however, fecal steroids do not follow the typical pregnancy pattern of felids (Brown et al., 1994b; Pelican et al., this book; Dehnhardt et al., this book) and, thus, have been considered an inappropriate method for monitoring reproductive activity.

Alternatively to fecal hormone metabolites, urine has been often used for tracking sexual hormones. Steroid hormones are secreted via the kidney into urine, mainly conjugated as sulfates or glucuronides. Those products are more water-soluble than the parent steroids (Dehnhard et al., 2006; Taylor, 1971). Additionally, several peptide hormones, like luteinizing hormone (LH), human chorionic gonadotropin (hCG) and relaxin, have been detected in urine and could be related to sexual activity or pregnancy status (Canfield et al., 1987; Steinetz et al., 1996; Cole, 1997; Jeffcoate and England, 1997). Relaxin, which is produced mainly by the placenta (Addiego et al., 1987), is a useful marker for pregnancy diagnosis. In the domestic cat, relaxin increases at the beginning of the second trimester (day 20 to 25) reaching a plateau and a subsequent decrease 10 to 15 days before parturition (Stewart

and Stabenfeldt, 1985). Recently, de Haas van Dorsser et al. (2006) have shown that relaxin is detectable in urine of pregnant domestic cats and leopards. Furthermore, a bench top kit (Witness® Relaxin) was successfully used for pregnancy detection in urine collected from domestic cats (Haas van Dorsser et al., 2007). Since urine collection from captive Iberian lynx was established to supply urine for camera trapping and identification of free-ranging lynxes and it is performed on a regular basis at the Ex situ Breeding Programme, the aim of the present study was to test whether urine could be effectively used for pregnancy diagnosis. Our study also focused on looking for a relaxin signal in serum obtained using a minimally invasive method that involved the use of triatomine, blook-sucking, insects (Voigt et al., 2004).

Material and methods

The Iberian lynx maintained under the umbrella of the *Ex situ* Conservation Programme are kept in three breeding centers (Vargas et al., 2008; Vargas et al., this book). This study took place at the El Acebuche Captive Breeding Center in Doñana National Park, in Southern Spain. The captive population consisted of 16 animals (seven males, nine females) in 2006 and of 52 (28 males, 24 females) in 2008 (Vargas et al., this book). The first birth in captivity was in 2005, since then 24 cubs have been raised in the Breeding Programme. Animals were kept in separate enclosures (550 m^2), and during mating season (January to February) all females were allowed to mate by introducing a male into the female's enclosure. Depending upon the female's behavior, the couples were maintained together for several weeks or just for the copulatory period. All behavioral interactions were recorded by remote video cameras (Vargas et al., this book). Mating was documented in all females, and the cycle was considered to involve a pseudo-pregnancy if no parturition or abortion was observed (Göritz et al., this book). Delivery of cubs was the final indication of pregnancy.

Blood plasma collection (adapted from Braun et al., 2008)

During two breeding seasons, plasma samples from five pregnant females were collected with triatomine, blood-suckling bugs (Voigt et al., 2004). Prior to the test, Iberian lynx females were encouraged to use cork plates as resting spots. As part of the daily routine, keepers would handle the corks so females would not be suspicious when the bugs were finally placed inside the corks (Figure 1). Since all enclosures were equipped with cameras, the time span during which each individual rested on the cork plate was monitored (Figure 2). After 30 min of uninterrupted resting (generally sleeping) on the plates, females were removed from the enclosure and bugs were taken out of the cork holes. Blood samples obtained from each bugs ranged from 0.5-2 ml (Figure 3). If samples were drawn carefully, bugs could be reutilized for other purposes, although never to draw blood again from another potentially pregnant Iberian lynx female. Blood was centrifuged to obtain plasma, a few drops of which were used for pregnancy diagnosis via Witness® Relaxin, while the remaining sample was sent for additional hormone and antibody analyses.

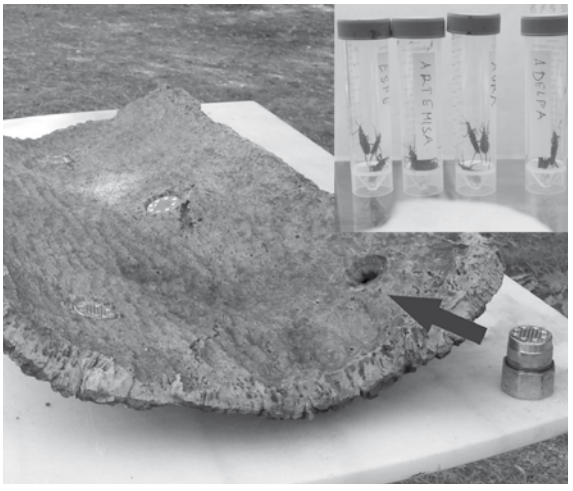

Figure 1. Cork plates, which lynxes use as resting spots, are equipped with holes for special containers containing blood-suckling bugs (arrow). As part of the daily routine, keepers would handle the corks so females would not be suspicious when the bugs were finally placed inside the corks. After installing the bugs into the cork plate, the bugs pierce its proboscis through the mesh, which closes the top of the container, to draw blood from a lynx resting on the cork plate.

Figura 1. Las planchas de corcho que los linces utilizan como lugares de descanso se modifican con agujeros donde se insertan contenedores especiales que sirven para ubicar a los insectos triatóminos (flecha). Como parte de la rutina diaria, los cuidadores manejan los corchos para que los linces no "sospechen" en el momento en el que finalmente se introducen los insectos. Una vez que los insectos están en las planchas de corcho, los insectos sacan su probóscis a través de la malla que cubre la parte superior del agujero y obtienen una muestra de sangre del lince mientras éste descansa en su corcho.

Figure 2. Iberian lynxes were monitored with cameras during the "bug sampling" procedure. On the computer monitor four different "houses" of the enclosures are visible. The upper screens show two resting sites equipped with a cork plates. The lower screens show females on the cork plates. The female on the left is resting. The one on the right lower screen is being released to the outside enclosure after 30 min motionless resting.

Figura 2. Durante el procedimiento "muestreo con insectos", se hizo un seguimiento de los linces mediante videovigilancia. En el monitor del ordenador se observan cuatro compartimentos diferentes de las instalaciones. En las dos pantallas superiores se ven las planchas de corcho con los agujeros que contienen los insectos. Las pantallas inferiores muestran las hembras sobre las planchas de corcho. La hembra de la izquierda está descansando; la de la derecha está saliendo hacia el cercado exterior después de un descanso de 30 minutos sin movimiento.

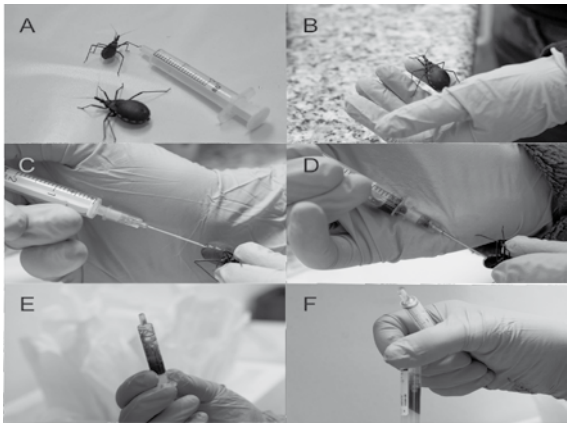

Figure 3. Sampling procedure from the filled blood suckling bug (A-F). (A): Triatomine bugs before (in the back) and after (in front) blood suckling. (B): Bug filled with ca. 1 ml blood. (C-D): Collection of ingested blood was performed with a 2 ml syringe. (E): After determination of volume, the samples was transferred to a serum tube (F) and centrifuged for plasma collection. An aliquote of "Bug" plasma was directly subjected to the Witness® Relaxin test.

Figura 3. Procedimiento de muestreo para extracción de sangre del insecto triatómino (A-F): (A): Chinche antes (al fondo) y después (al frente) de succionar la sangre. (B): Insecto tras ingerir 1 ml de sangre. (C-D): La extracción de sangre se lleva a cabo con jeringas de 2 ml. (E): Tras determinar el volumen, las muestras se transfieren a un tubo de desuerado (F) y se centrifugan para la recolección del plasma.
Una alícuota de plasma obtenido mediante el insecto se utiliza para realizar el test Witness® de relaxina.

Urine sampling and reproductive status (adapted from Jewgenow et al., in press)

Urine was collected from six different females by placing homemade collectors in their enclosures. The collectors consisted of vertical stainless steel plates (60 x 60 cm) ending in gutters at the bottom and a slight v-shape inclination that allowed the urine to run into a collector cup. Lynxes used these plates to mark their territories (Figure 4). Urine samples (10 to 50 ml) were collected daily and stored at -20 °C. During the breeding season (January to April), samples were obtained 2-3 times per week, for the rest of the year at least one sample per month per animal was used. Table 1 presents the samples available for this study.

For steroid analysis, urine aliquots of 100 µL were hydrolysed, extracted and subjected to hormone assays

Figure 4. An Iberian lynx marks the urine collector in its enclosure. The urine was freshly collected for relaxin determination.

Figura 4. Un lince ibérico marca el colector de orina ubicado en su instalación. La orina se recoge en fresco para realizar el test de relaxina.

	Number of females (n=number of samples)			
Status	non-pregnant	pregnancy	pseudo-pregnancy §	non-breeding
Season	breeding	breeding	breeding	outside breeding season
Mating	no mating	mating	mating	-
Parturition	no	cubs born	no cubs	-
2006	-	2 (n=48)	1 (n=18)	3 (n=45)
2007	-	6 (n=143)*	-	6 (n=240)
2008	1 (n=20)	3 (n=105)	-	4 (n=62)
Σ	1 (n=20)	8 (n=237)# 3 (n=59)*	1 (n=18)	13 (n=347)

§ The pseudo-pregnancy might be the result of either an infertile mating or early embryonic death.
*** Three females were kept together with their mates during the entire pregnancy.**
 # Number of females kept during sample collection alone (n=pure female urine samples).

Table 1. Collection of urine samples from female lynx at the El Acebuche Iberian Lynx Captive Breeding Center during breeding (January-April) and non-breeding (May-December) seasons 2006 to 2008 (Jewgenow et al., in press).

Tabla 1. Recogida de muestras de orina de hembras de lince en el Centro de Cría en Cautividad El Acebuche durante las épocas reproductivas (enero-abril) y no reproductivas (mayo-diciembre) entre 2006 y 2008 (Jewgenow et al., en imprenta).

as described before (Jewgenow et al., in press). Urinary hormone concentrations are expressed as ng per mg creatinine in order to control for differences in urine concentration.

Progesterone (P4) determination

Urinary progesterone was determined by enzyme immunoassays based on a rat antibody (Sigma P1922, generated to progesterone) together with 4-pregnen-3,20-dione-3-CMO-peroxidase as label (Göritz et al., 1997; Dehnhardt et al., 2006). The cross-reactivity's of both antibodies and their inter- and intra-assays coefficients were as described before (Braun et al., 2008).

Estrogen (E2) determination in urine samples

Estrogen analyses were carried out with an in-house microtitre plate enzyme immunoassay using a polyclonal antibody (rabbit) against 1,3,5(10)-estratrien-3,17ß-diol-17-HS-BSA and 1,3,5(10)-estratrien-3,17ß-diol-17-HS-peroxidase label (Meyer et al., 1997). The cross-reactivities of antibodies and inter- and intra-assay coefficients were as described before (Jewgenow et al., in press).

Ultrafiltration of urine samples for Relaxin determination

Urine samples were subjected to ultrafiltration (Braun et al., 2008). In brief, microcon YM50 unit (Millipore®, USA) were used to separate high molecular proteins by centrifugation (14000 x g, 4 °C). The flow through (low molecular peptides) was subjected to a second ultrafiltration step with a centricon YM3 (Millipore®, USA) separating proteins larger then 3 kDa molecular weight (7500 x g, 4 °C). At this stage, relaxin and other 3-50 kDa proteins were supposed

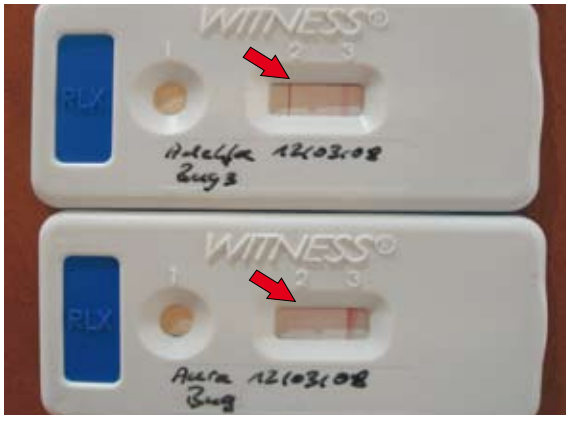

Figure 5. Witness® Relaxin tests were performed with bug ingested lynx blood plasma or highly concentrated urine samples (x 50). The positive lines (arrows) are an indication for relaxin in the sample, whereas a missing signal in line 2 must be judged carefully, because the hormone levels might below the detection level.

Figura 5. Las pruebas Witness® de relaxina se llevaron a cabo con plasma obtenido a través de sangre de lince ingerida por insectos triatóminos o mediante muestras de orina altamente concentradas (x 50). Las líneas positivas (flechas) indican la presencia de relaxina en la muestra, mientras que la falta de señal en la línea 2 debe ser interpretada con cautela.

to be retained on the membrane. Samples were centrifuged (after washing with PBS) until almost no further volume decrease was attained. Finally, urine samples were concentrated up to ninety times of the original urine volume.

Test with Witness® Relaxin (Synbiotics Corporation)

Blood plasma samples drawn from bugs were directly subjected to Witness® Relaxin test according to the manufacture's instructions. In brief, two drops of plasma were transferred to the sample well followed by two drops of the provided buffer. Within the reading window, the result of the test was visible after at least 15 minutes (Figure 5). The appearance of a specific relaxin and a control band was judged as an indication of relaxin in blood serum. A missing relaxin band after a prolonged time (1 hour) was an indication of a negative test result.

Urine samples were processed as described by de Haas van Dorsser et al. (2007). Thus, urine was mixed with equal amounts of lynx blood serum (serum from a non-pregnant Iberian lynx female obtained during chemical immobilisation in November 2006) before it was subjected to the Witness® Relaxin test. In case of concentrated urine samples, they were diluted with of blood serum from a non-pregnant Eurasian lynx and 64 µL of the urine-serum mixture (estimated volume of two normal blood drops) was added to the sample well followed by two drops of the provided buffer. Positive relaxin signals were seen in the reading window within at least 20 minutes after application; control bands were visible in every test.

Statistics

The results of urinary steroid hormone determination were expressed as immunoreactive steroid in ng per mg creatinine. Data presented as means ± standard errors of the mean (SEM). Comparisons of means values were performed by Welch corrected unpaired t-Test. All statistical tests were based on a 5% level of significance. The statistical procedures were performed with the software programme Instat Version 3 (Graphpad Software Inc.).

Results and discussion

Urinary P4 levels did not reveal a distinct increase during pregnancy compared to non-breeding season levels (Table 2). Also, no difference was found in progestin concentrations when non-pregnant (no mating), pregnant

Immune reactive steroid ng per mg creatinine (number of samples)	Outside breeding season Means (± SEM)	Pregnancy (day 1 to 64) Means (± SEM)	Unpaired t test with Welch correction
Progesterone (n)	1.8 ± 0.05 (347)	2.4 ± 0.1 (237)	t =1.93, P > 0.05
Estrogens (n)	8.6 ± 0.6 (342)	8.6 ± 0.5 (237)	t=14.28, (P<0.001)

Table 2. Determination of steroid concentration in urine samples collected from female Iberian lynx outside the breeding season, either before or after pregnancy, versus during pregnancy. Mean values were calculated for all samples available not discriminating between individuals (Jewgenow et al., in press).

Tabla 2. Determinación de la concentración de esteroides en las muestras de orina recogidas de hembras de lince ibérico en época no reproductiva, antes o después de la gestiación, comparado con las recogidas durante la gestación. Se calculó el valor medio de todas las muestras, sin distinguir ejemplares. (Jewgenow et al., en imprenta).

		Progesterone in ng/mg creatinine (n samples)	Estrogens in pg/mg creatinine (n samples)
Artemisa	Outside breeding season (May – Dec)	2.0 ± 0.2 (47)	2.8 ± 0.2 (47) [A,B]
	# Pregnancy 2007	1.0 ± 0.7 (16)	46.8 ± 2.7 (15) [A,C]
	Breeding season 2008 (Jan – April)	1.5 ± 0.3 (20)	0.8 ± 0.2 (20) [B,C]
Aura	Outside breeding season (May – Dec)	1.9 ± 0.1 (97)	3.9 ± 0.3 (96) [D,E]
	Pseudo-pregnancy (mating, no birth)	4.4 ± 1.4 (18)	9.2 ± 1.0 (18) [D,F]
	Pregnancy 2007/2008	3.0 ± 0.2 (40)	12.1 ± 1.3 (38) [E,F]

 # Sample collection was performed in the presence of male.
a-f Identical superscripts indicate statistical differences between estrogen concentrations estimated by unpaired t test with Welch correction.

Table 3. Urine estrogens and progesterone in urine samples of a non-mated *(Artemisa)* and pseudo-pregnant *(Aura)* in relation to samples collected outside breeding season and pregnancy (Jewgenow et al., in press).

Tabla 3. Estrógenos y progesterona urinaria de una hembra no apareada *(Artemisa)* y una pseudogestante *(Aura)*, comparadas con las muestras recogidas fuera de la época de reproducción y de embarazo (Jewgenow et al., en imprenta).

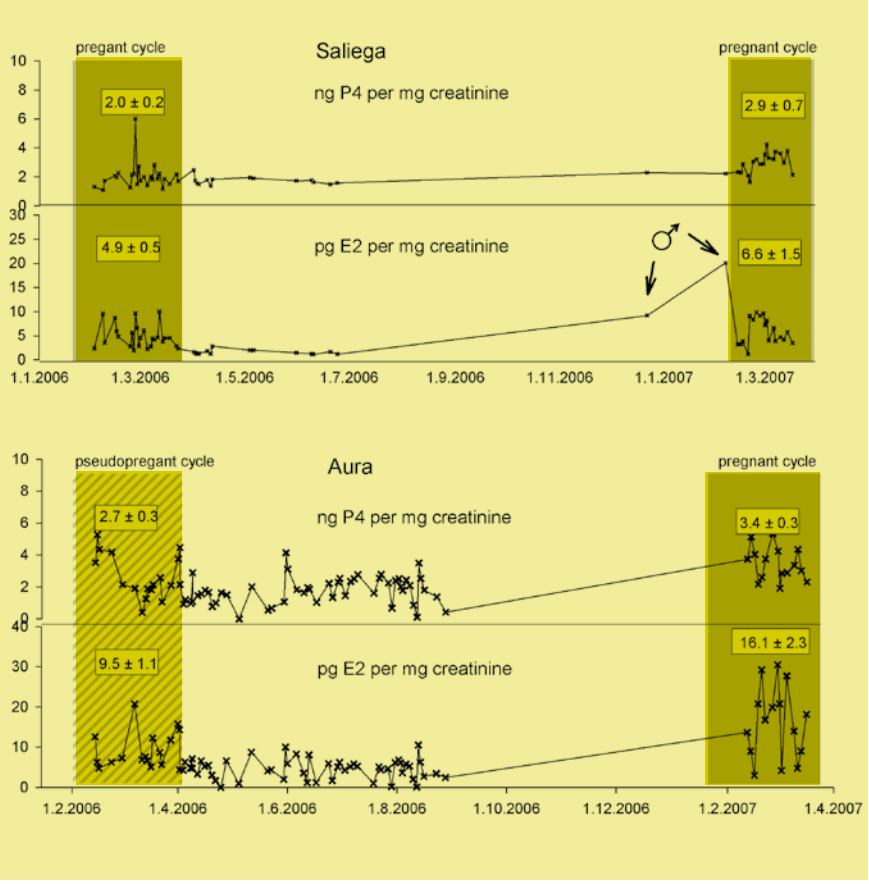

Figure 6. Determination of progesterone (P4) and estradiol (E2) in extracts of urine collected from female Iberian lynx. As an example, seasonal patterns of two adult females –*Saliega* (upper panel) and *Aura* (lower panel)– are presented. *Saliega* was pregnant (grey block) in 2006 and 2007, whereas *Aura* mated in 2006, but did not conceive (pseudo-pregnancy, lined block). In 2007, she delivered three healthy cubs after 64 days of pregnancy (green block). Arrows indicate the presence of a male sharing the enclosure with the female.

Figura 6. Determinación de la progesterona (P4) y el estradiol (E2) en extractos de orina de hembras de lince ibérico. Como ejemplo se muestran los patrones estacionales de dos hembras adultas –*Saliega* (panel superior) y *Aura* (panel inferior). *Saliega* quedó gestante (bloque gris) en 2006 y 2007, mientras que *Aura* se apareó en 2006 pero no quedó gestante (pseudogestación, bloque con rayas). En 2007, *Aura* tuvo tres cachorros sanos tras 64 días de gestación (bloque verde). Las flechas indican la presencia de un macho compartiendo instalación con la hembra.

and pseudo-pregnant lynx cycles were compared directly within the same animals in different years (Table 3, Figure 6, *Aura*). The mean progesterone concentrations were slightly lower, when no mating occurred (Table 3, *Artemisa*), but progesterone levels of pseudo-pregnant and pregnant cycles did not differ significantly. Thus, urinary progesterone may indicate the existence of corpora lutea after induced ovulation, but a reliable pregnancy diagnosis based on progesterone was unattainable. In this respect, urinary progesterone follows the pattern described for fecal progestagen excretion in Iberian lynx females (Pelican et al., this book). In contrast to many other felid species (Brown et al., 1994a), pregnancies in Iberian lynx are not characterized by elevation of either fecal (Pelican et al., this book) or urinary progesterone concentration (this study). We suggest that this might be the consequence of the prolonged presence (and function) of corpora lutea throughout most of the year (Kvam, 1990; Göritz et al., this book). Thus, a permanent progestin production may ensure the strong seasonality in lynx (but masks any changes associated with the luteal phase of pregnancy).

In most felids, increased estradiol excretion is associated with estrus behaviour or exogenous gonadotropin treatment (Brown et al., 1994b). Unfortunately, the collection of urine samples from individual females during the period of mating was impossible, since the husbandry scheme allows breeding pairs to share enclosures until two weeks before parturition. Therefore, we were unable to detect a mating-related urinary estrogen peak. Urine samples collected from females with males were characterized by several-fold higher ($t=35.2$, $P<0.0001$) estrogen concentrations (66.8 ± 5.7 ng E2 per mg creatinine; n=59) in comparison to pure female urine samples (means of all females: 5.7 ± 0.2 ng E2 per mg creatinine, n=611). The elevated estrogen concentrations in mixed male and female urine were found not only during co-housed pairs immediately before and during the mating period (and thus possibly related to estrus of the female), but was also seen when the couples were left together during pregnancy (three females in 2007, Table 1; *Artemisa*, Table 3). It is likely that urine from male

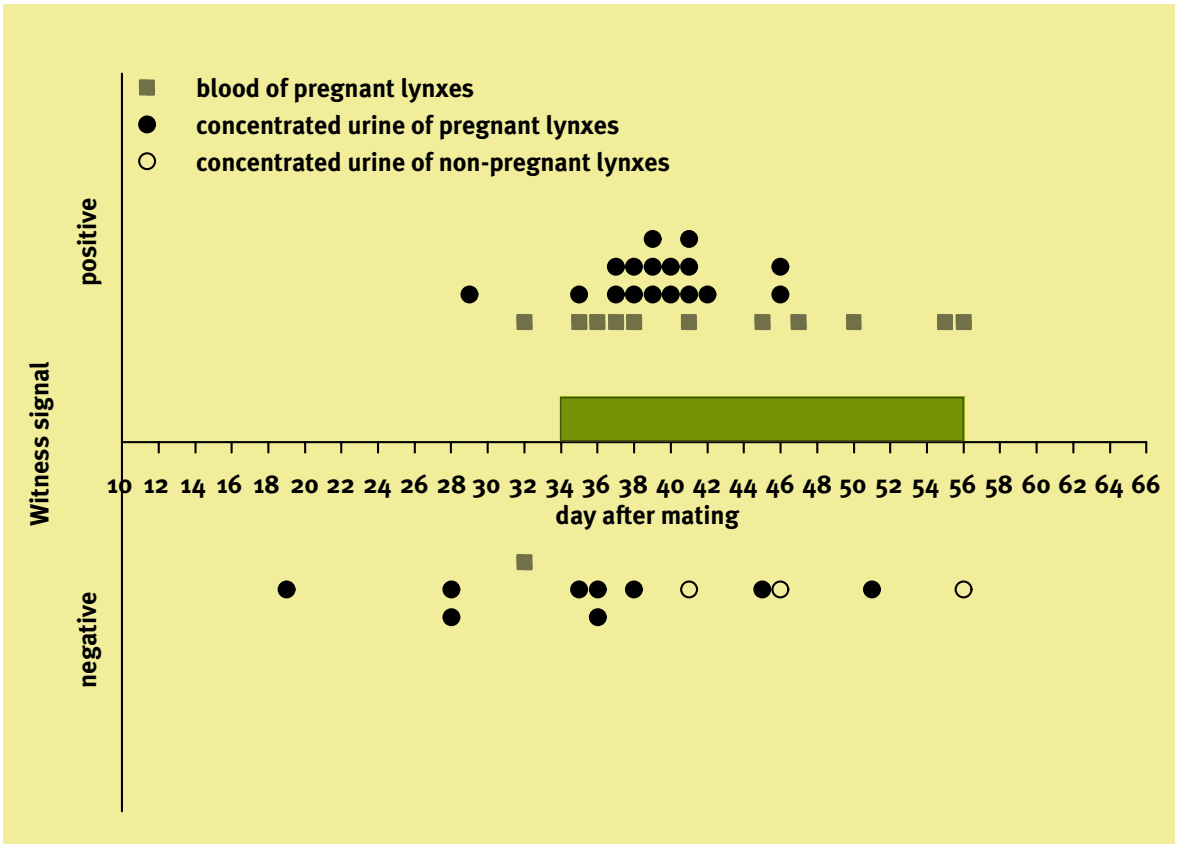

Figure 7. Witness®Relaxin test results of urine and blood samples of pregnant and non-pregnant Iberian lynxes. Pregnancy could by diagnosed with blood samples –obtained via triatomine bugs– between days 31 and 52 after the first mating. The one pregnant animal which shows a negative signal at day 31 (marked by asterisk) was later detected as pregnant via urine test in day 42. Her urine sample of day 38 after mating (marked by an asterisk) was negative too. Urine samples of other pregnant females showed positive signals with samples that were collected between days 37 to 47 after mating. Urine samples of non-pregnant lynxes in this period also yielded negative results.

Figura 7. Resultados de la prueba Witness® Relaxin realizada en muestras de orina y sangre de hembras de lince ibérico gestantes y no gestantes. La gestación de las hembras de lince pudo ser diagnosticada en muestras sanguíneas –obtenidas mediante insectos triatóminos– entre los días 31 y 52 después del primer apareamiento. La única hembra gestante que dio un resultado negativo en el día 31 tras la primera cópula observada (marcada con asterisco) dio posteriormente un resultado positivo a la relaxina en una muestra de orina tomada el día 42, siendo negativa también su muestra de orina del día 38 después del apareamiento (marcado con asterisco). Las muestras de orina de otras hembras gestantes fueron positivas a la relaxina cuando fueron recogidas entre los días 37 y 47 después del apareamiento. Las muestras de orina de las hembras no gestantes durante este período dieron resultados negativos.

lynx contains estrogen concentrations that could be up to 10-fold higher than female urine. Within the Iberian Lynx Captive Breeding Programme the collection of samples to monitor the onset of estrus in the absence of males was not possible, since all females were sharing enclosures with males prior to entering estrus. Yet, such information would be valuable for further characterization and for better understanding the onset of the Iberian lynx breeding season.

Nevertheless, in the absence of males, estrogens were still significantly elevated ($P<0.001$) during pregnancy (8.6 ± 0.5 ng E2 per creatinine, mean of all animals, Table 2) when compared to samples collected out of the breeding season (3.8 ± 0.2 ng E2 per mg creatinine). Figure 6 also demonstrates the considerable day-to-day variability of urinary estradiol concentrations and emphasizes the need for frequent sample collection in order to detect Iberian lynx pregnancies and to avoid potentially false negative results (E2 below 5 ng per mg creatinine).

The results from the female *Artemisa* (Table 3) showed a significant difference ($P<0.001$) in urinary estrogens between her non-breeding (2.0 ± 0.2 ng E2 per mg creatinine) and breeding (1.0 ± 0.7 ng/mg creatinine) seasons, a year in which she did not accept any male for copulation and, thus, did not have the chance to get pregnant.

Unfortunately, during her pregnancy in 2007, this female was kept together with a male and data on urinary estrogens (46.8 ± 2.7 ng E2 per mg creatinine, Table 3) were not suitable for comparative analysis. Although samples from only one female that failed to copulate were available, the low estrogen levels in *Artemisa* during the 2008 breeding season are an indication of the missing ovulation and corpora lutea (CL) formation.

We conclude that Iberian lynx are induced ovulators as described for many other felid species (Brown and Wildt, 1997). In contrast, the direct comparison of pregnant cycles (12.1 ± 1.3 ng E2 per mg creatinine) with pseudo-pregnant cycles (9.2 ± 1.0 ng E2 per mg creatinine) revealed a further increase of urinary estrogens caused by implantation (*Aura*, Table 3, Figure 6). Thus, if mating occurs, corpus luteum (Cl) formation is evident by elevated estrogens and ultrasound examination (Göritz et al., this book). The increase in estrogens in pregnant versus pseudo-pregnant cycles, might be either explained by a shorter half-life of the Cl in pseudo-pregnant cycles, as described for domestic cats, (Tsutsui and Stabenfeldt, 1993) or by estrogen production by fetal structures (placenta), which is physiological in other species, such as cattle (Hoffmann et al., 1997), pigs (Knight and Kukoly, 1990) and horses (Möstl, 1994).

The Witness®Relaxin test (Figure 5) yielded positive results in plasma samples in four out of five animals in 2007 and in all seven animals tested in 2008 (Figure 7). The positively tested animals were all between day 32 and 56 of pregnancy, of a 63-66 day gestation period (Vargas et al., this book). The animal whose plasma yielded negative Witness®Relaxin test results, was at day 32 after her first mating, although later she was proven to be pregnant. In contrast to urine of domestic cats (de Haas van Dorsser et al., 2006), Witness®Relaxin test failed in both fresh and frozen native urine samples. Only when urine samples were concentrated by ultrafiltration at least 50x, a weak relaxin positive reaction was observed between day 29 and 46 of the pregnancy (n=17). No urinary relaxin signal from pregnant animals was detected in some occurrences (n=5); these urines were collected on days 35, 36, 38 and 45 from pregnant animals (Figure 7). These failed pregnancy diagnosis might be explained by the ongoing degradation of relaxin within the urine samples (late collection) and/or insufficient level of the ultrafiltration procedure. Thus, the urinary relaxin was still under the detection level of Witness®Relaxin test. All concentrated urine samples from non-pregnant females yielded negative relaxin results, as well as did those urine samples of pregnant females in early (before day 29) and late (after day 50) gestation (Figure 7).

Conclusions

The present results suggest that pregnancy-related hormone activity in Iberian lynx can be monitored by urinary estrogens if samples are collected frequently and in the absence of males in the enclousure. In contrast to urinary progestagens, estrogens reflect Cl formation after ovulation. Furthermore, the observed increase of urinary E2 after mating and during late pregnancy suggest either an E2 secretion from the lynx placenta and/or a pregnancy-specific enhanced luteal secretion of estrogen, a point for additional study. In addition, pregnancy diagnosis is attainable by applying the Witness® Relaxin bench top test, if blood plasma or highly concentrated urine samples are used. Relaxin can be detected in a certain period during pregnancy, which ranges between 34 to 50 days after mating for blood plasma, and day 37 to 46 post-mating days for urine samples, respectively.

Acknowledgements

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Photo: Antonio Rivas

Study nature, love nature, stay close to nature.
It will never fail you.

Frank Lloyd Wright
(1867-1959)

Photo: Tanya Shenk

Reproductive physiology of Canada lynx *(Lynx canadensis)*

Fisiología reproductiva del lince canadiense *(Lynx canadensis)*

Kerry Fanson, Nadja Wielebnowski and Jeffrey Lucas

Resumen

Este estudio tiene como objetivo validar las pruebas para la detección de distintos metabolitos hormonales en heces de lince canadiense y obtener conocimientos básicos sobre su fisiología reproductiva. Mediante las técnicas de laboratorio empleadas en este estudio se consiguió validar la metodología para detectar los andrógenos fecales en los machos, y los análisis revelaron un incremento estacional claro en los niveles de andrógenos antes y durante la época de reproducción. La validación de ensayos para estrógenos y progestágenos no fue completamente convincente, aunque sí informativa. En las hembras se observó un aumento significativo en los niveles de estrógenos durante la época reproductora. La validación del ensayo no fue concluyente en parte debido a la persistencia inusualmente prolongada de cuerpos lúteos, lo que posiblemente produzca distintos perfiles hormonales en las hembras de lince comparadas con las de otros mamíferos. Asimismo, se validó una prueba para detectar glucocorticoides en heces de machos y hembras. Encontramos indicios preliminares de que las hembras tienen una respuesta fisiológica más marcada ante el estrés que los machos, aunque esto no significa necesariamente que las hembras sean más sensibles al estrés. El estrés crónico (por ejemplo, por translocación o contención) parece suprimir la expresión de andrógenos en los machos. Sería necesario llevar a cabo más estudios para obtener un conocimiento más claro sobre cómo afectan los factores estresantes presentes en el entorno a la reproducción del lince canadiense y, por ende, a su tamaño poblacional. Un mayor conocimiento sobre la fisiología reproductiva del lince podría ayudar a mejorar las prácticas de conservación.

Palabras clave

Hormonas fecales, estacionalidad, estrés

Abstract
Knowledge about the reproductive physiology of lynx could help improve conservation practices. The goal of this study was to validate fecal hormone metabolite assays for Canada lynx and develop a basic understanding of their reproductive physiology. Fecal androgen assays were validated for males, and analysis revealed a clear seasonal increase in androgen expression immediately prior to and during the breeding season. The validation of fecal estrogen and progestagen assays for females was not entirely convincing, but nevertheless informative. A significant rise in fecal estrogens was observed during the breeding season for females. Assay validation may be partially confounded by the unusually long persistence of corpora lutea in Lynx species, which could produce different hormone profiles compared to other female mammals. Lastly, a fecal glucocorticoid metabolite assay was validated for both males and females. We found preliminary evidence that females may have a more pronounced physiological stress response than males, although this does not necessarily imply that females are more sensitive to stress. Chronic stress (e.g. translocation and holding) does appear to suppress androgen expression in males. Further research is needed to gain a clearer understanding of how environmental stressors may impact Canada lynx reproduction, and thereby affect their population size.

Keywords
Fecal hormones, seasonality, stress

Photo: Tanya Shenk

Reproductive physiology of Canada lynx *(Lynx canadensis)*

Kerry Fanson, Nadja Wielebnowski and Jeffrey Lucas

Introduction

Canada lynx *(Lynx canadensis)* are the most abundant felid species inhabiting North America's boreal forest. However, southern populations of lynx have declined dramatically in the last century, and in 2000, the species was listed as "threatened" by the US Fish and Wildlife Service (USFWS, 2000). While lynx historically extended well into the northern continental US, anthropogenic activities (e.g. trapping, habitat destruction) and climate change have dramatically reduced most US populations (Ruggiero et al., 2000; Poole, 2003). In response to this decline, the state of Colorado initiated a lynx reintroduction effort in 1999 (see Shenk, this book). However, poor reproductive success of reintroduced individuals has threatened the success of this effort.

There are two characteristics of lynx reproduction that may contribute to their diminishing population size and hinder reintroduction efforts. First, Canada lynx are highly seasonal breeders; they have only one chance per year to reproduce (Poole, 2003). They breed from late February to early April and give birth primarily in May, with a gestation period of 60-70 days (Nowak, 1999; Ruggiero et al., 2000). Even in the southern part of their range and in captivity, females only breed once per year and most kittens are born in May. Although the breeding season lasts about two months, individual females may have a much more restricted window of mating opportunity. Captive females exhibit signs of estrus or receptive behavior for about one week or less. Little is known about estrus in wild lynx, but behavioral indicators suggest that females are only receptive for a short period. Mating pairs only remain together for several days and females presumably mate with only one male (Ruggiero et al., 2000). There is no published information about the duration or the length of estrus in captive or wild Canada lynx (Nowak, 1999). Furthermore, it is unclear whether this strong seasonality is mediated solely by females, or if both females and males experience physiological changes that may restrict their ability to mate throughout the year.

The second characteristic is that lynx recruitment fluctuates dramatically with snowshoe hare abundance, especially in the northern part of their range (Ruggiero et al., 2000). Pregnancy/conception rates, birth rates, average litter size and kitten survival, all correlate positively with prey abundance, whereas female age at sexual maturity correlates negatively (Ruggiero et al., 2000; Poole, 2003). Biologists have also speculated that females ovulate spontaneously when prey densities are high, but become induced ovulators when prey

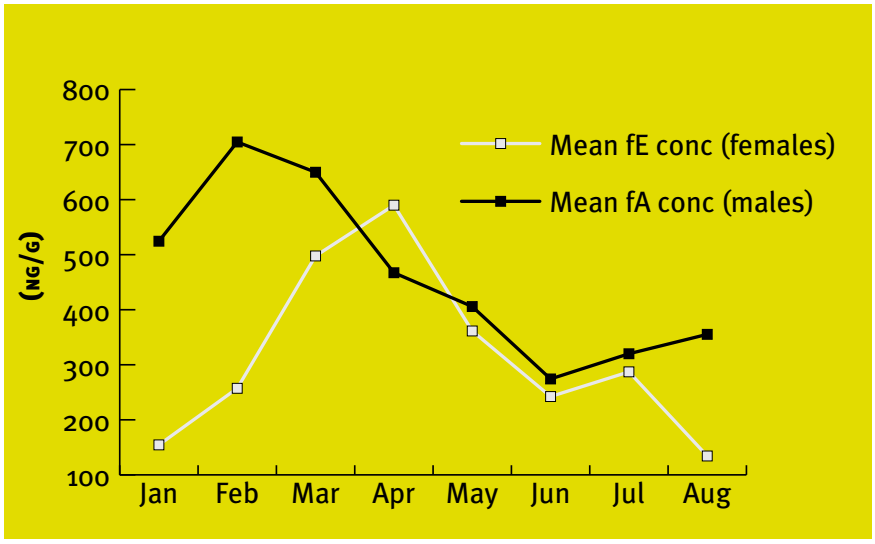

Figure 1. Seasonal changes in fecal androgen metabolites (fA) for males (♂), and fecal estrogen metabolites (fE) for females (♀). Means are plotted for intact, adult lynx. Breeding season is primarily during March.

Figura 1. Cambios estacionales en metabolitos de andrógenos (fA) en heces de machos (♂) y metabolitos de estrógenos (fE) en heces de hembras (♀). Se trazaron los valores medios para linces adultos. La época de reproducción tiene lugar principalmente durante el mes de marzo.

densities are low (Ruggiero et al., 2000). The reproductive physiology of lynx is therefore closely linked to the health of the snowshoe hare population, to the point that there is little to no recruitment during the low part of the cycle (Ruggiero et al., 2000; O'Donoghue et al., 2001; Poole, 2003). Consequently, lynx experience both annual and decadal restrictions to breeding.

Given these constraints to Canada lynx reproduction, it is unclear how climate change or anthropogenic activities may impact lynx reproduction. In order to develop effective conservation strategies and management plans for lynx, it is critical that we develop a stronger understanding of their reproductive physiology. To this end, we have initiated a research project focusing on the endocrine physiology of both captive and wild Canada lynx using fecal hormone analysis. The goal of the study described here was to 1) validate assays used to quantify fecal reproductive and glucocorticoid ("stress") hormone metabolites; 2) establish normative patterns of reproductive hormone expression in captive Canada lynx, and 3) provide a preliminary examination of the effects of stress on reproductive physiology.

Fecal samples were collected from two populations: 1) lynx in captivity and 2) lynx in holding pens. "Captive" lynx were permanently housed at captive institutions (zoos and breeding centers) and had lived in captivity most, or all, of their life. "Holding pen" lynx had been trapped in Canada or Alaska, transported to Colorado and housed in holding pens for ~2 months before they were reintroduced. Samples were collected 3-6 times per week. Hormone metabolite extraction and enzyme-immunoassay procedures have been previously described (Atsalis et al., 2004; Cavigelli et al., 2006).

Male reproductive physiology

Samples were collected from eight adult males housed at seven institutions. Two males, both housed alone, had been castrated. The remaining six males were all housed with intact females. Ages ranged from 4-18 years. Samples were also collected from two juvenile (<9 months) males.

Validation – Fecal androgen metabolites (fA) are reliable indicators of testicular activity in lynx. Both juvenile and castrated males had much lower fA concentrations than intact males (mean ± SE: 35.4 ± 30.7, 225.4 ± 63.2, 637.1 ± 116.3 ng/g feces, respectively). However, we still detected a moderate amount of fA in castrated males. There are several possible explanations for this. First, another source of androgens could contribute to circulating levels, and thereby excreted quantities, of androgens in castrated males. In humans and primates, the adrenal cortex produces a number of androgens (e.g. DHEA and DHEA-S, Rehman and Carr, 2004). Secretions of the adrenal cortex in lynx have not been studied, but could contribute to fA levels in castrated males. Second, hepatic metabolism or bacterial activity could convert other steroid molecules into androgens (Touma and Palme, 2005). A final possibility is that the antibody used cross-reacts with other steroid metabolites, because

a non-specific, relatively broad-spectrum antibody was used. Regardless of which explanation is true, the assay is reliably detecting significant and biologically relevant signals, and thus can be successfully employed to track androgen excretion in male Canada lynx.

Effect of Season – Male lynx exhibit strong seasonal variation in fA expression (Figure 1). Just prior to and during the breeding season (Jan.–Mar.), fA concentrations are ~4-times higher than during the summer. Although we do not have data for the fall, we can speculate that fA concentrations (and thus testicular activity) begin to increase late in the fall (Nov. or Dec.). Living at high latitudes and/or elevations, lynx experience very harsh winters. Therefore, in order to ensure optimal kitten survival, strong selection pressure has probably shaped not only female patterns of reproduction, but has constrained male reproduction, as well.

Eurasian lynx exhibit similar patterns of seasonality. However, captive male Eurasian lynx have a second increase in testosterone expression and testicular size in May and June (Göritz et al., 2006). This may possibly be driven by the fact that if a female Eurasian lynx loses a litter, she can begin cycling again in June or July (Göritz et al., 2006). There is limited anecdotal evidence that female Canada lynx can also give birth in August, which means there would be a second period of estrous in May or June (J. Vashon and J. Tremblay, pers. comm.). However, we did not see a second increase in fecal androgens in May or June for any of the males in the study. The frequency of this "second estrous" in females is not known for either species, although it seems very rare for Canada lynx. Given the differences in androgen expression between Eurasian and Canada lynx, we can speculate that a second estrous may be somewhat more likely to occur in Eurasian lynx.

Female reproductive physiology

Samples were collected from nine females housed at seven institutions. One female had been spayed and was housed alone. Six of the females were housed with intact males and given the opportunity to breed, but only three females got pregnant. The remaining two females were housed with each other. Ages ranged from 3-17 years.

Validation – The evidence that fecal estrogen metabolites (fE) reflect ovarian activity is somewhat equivocal. The spayed female did show significantly lower fE concentrations than intact females (mean ± SE: 324.4 ± 57.1, 802.7 ± 182.2 ng/g feces, respectively) suggesting that the assay does detect biologically relevant changes in estrogen expression. Furthermore, there are also seasonal increases in fE expression that coincide with the breeding season (Figure 1). However, we have failed to detect fE peaks associated with documented estrous behavior or known ovulations/matings. Lynx defecate about once per day, so if ovulatory estrogen spikes are very short-lived, they may be muted in the fecal sample. Therefore, it is possible that fE can be used to measure gross differences in ovarian activity, but not to monitor distinct ovarian events for this species.

A common progestogen EIA assay, which has been validated successfully for several other felid species, did not pick up relevant hormone metabolites for monitoring pregnancy in Canada lynx. We were only able to obtain data from three successful pregnancies, but the expected increase in fP concentrations could not be detected in any of the females with the initial assay (Figure 2). To further determine whether improper antibody binding (e.g. high cross-reactivity) was interfering with our ability to detect a rise in hormone concentrations generally expected during pregnancy, we then tested four other progesterone antibodies. While some antibodies indicated a slight increase in fP towards the end of the pregnancy, none show the characteristic elevation seen in some other felid species (e.g., domestic cat, tiger, cheetah, clouded leopards – J. Brown, this book).

However, while fPs could not be used to accurately detect pregnancy in Canada lynx, the measured concentrations may nevertheless accurately reflect luteal activity. There is evidence that corpora lutea (CLs) persist for extensive periods of time in Canada lynx (Nellis et al., 1972). In fact, this phenomenon is common to all Lynx species; CLs can persist for several months, and probably years (bobcats – Duke, 1949; Eurasian and Iberian lynx – Göritz et al., this book). Duke (1949) proclaims "[t]he life history of the corpus luteum of the bobcat is an intriguing puzzle." Indeed, this puzzle seems to be relevant to the entire Lynx genus. It is unclear how long the CLs remain capable of producing progesterone, but this could explain the difficulty that other Lynx researchers have also had in identifying pregnant lynx using fecal hormone analysis (Pelican et al., this book; Jewgenow et al., this book; Dehnhardt et al., this book). It is also unclear how females might accommodate this prolonged elevation of circulating progesterone while maintaining normal patterns of reproduction.

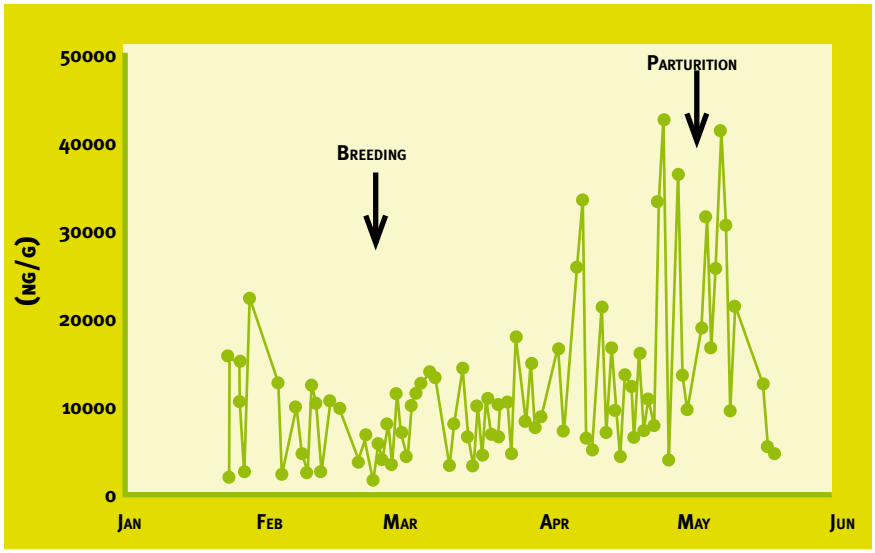

FIGURE 2. REPRESENTATIVE PROFILE OF FECAL PROGESTOGEN METABOLITE (FP) EXPRESSION IN A PREGNANT LYNX.

FIGURA 2. PERFIL QUE REPRESENTA DE LA EXPRESIÓN DE LOS METABOLILTOS DE LA PROGESTERONA (FP) EN UNA HEMBRA GESTANTE DE LINCE.

Another unexpected finding is that fE and fP show correlated patterns of expression. This is contrary to what we would expect to see, because luteal production of progesterone typically suppresses estrogen secretion, so these hormones should be inversely related. At this point, it is unclear what is causing this trend, but there is a possibility that it is related to the unusual CL characteristics of lynx.

STRESS & REPRODUCTION

Normative patterns of reproductive physiology can be dramatically altered by stress. A prominent component of the physiological stress response is the hypothalamic-pituitary-adrenal (HPA) axis. Chronic up-regulation of the HPA axis can negatively affect the hypothalamic-pituitary-gonadal (HPG) axis, and thus suppress reproduction (Wingfield and Sapolsky, 2003). However, the interaction between the HPA and HPG axes is highly variable between species (Wingfield and Sapolsky, 2003). Understanding how environmental stressors may affect reproduction requires a species-specific understanding of how the HPA and HPG axes interact. Here we provide a preliminary examination of how stress might affect reproduction in lynx.

The glucocorticoid assay was validated by monitoring patterns of hormone expression during ACTH challenges (Figure 3), transfers/translocations, and exams. Results revealed that female lynx have significantly higher fecal glucocorticoid (fGC) concentrations than males. Furthermore, the relative difference in fGCs between "captive" and "holding pen" lynx (see Introduction for description) is much greater for females than males (Figure 4). Gender differences in fGC expression have been documented for a wide range of species (Touma and Palme, 2005). One explanation, which has been confirmed in some species, is that there are gender-based differences in steroid hormone production and/or metabolism (Touma and Palme, 2005). Another explanation, which is not necessarily mutually exclusive with the first, is that these differences may reflect differences in stress sensitivity. It remains unclear which is true for Canada lynx.

It is of course difficult to experimentally examine the effect of chronic stress on reproduction in a threatened species, and data collection is mostly opportunistic. However, using data collected from the reintroduced lynx population in Colorado, we have preliminary evidence that chronic elevation of the HPA axis may suppress the HPG axis, at least in males. The winter during which lynx are trapped, transported, examined, and held in holding pens, fA levels are lower and fGC levels are higher than in subsequent winters, after they have been released. We do not yet have data for females since this study is still ongoing. However, especially given the tremendous impact that hare density has on lynx reproduction, it will be key to develop a better understanding of how environmental factors and potential stressors impact reproductive physiology in this species.

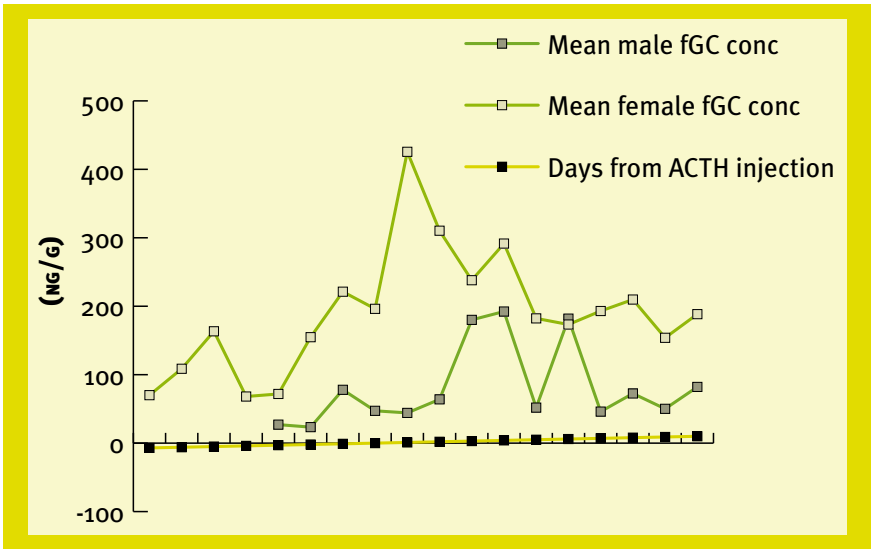

Figure 3. Mean fecal glucocorticoid metabolite (fGC) concentrations for two males (♂) and three females (♀) following an ACTH challenge (Day 0).

Figura 3. Concentración media de los metabolitos de glucocorticoides en dos machos (♂) y tres hembras (♀) de lince canadiense tras el desafío con la hormona ACTH (Día 0).

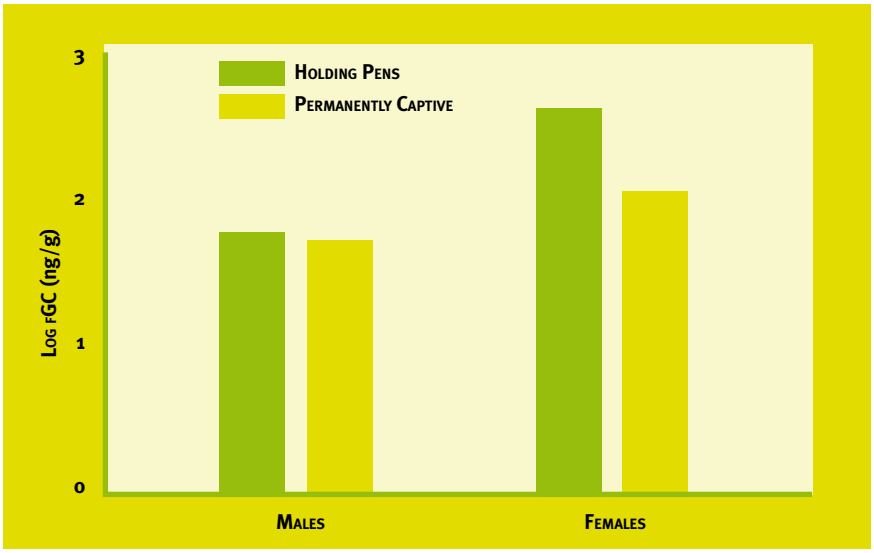

Figure 4. Gender differences in fecal glucocorticoid metabolite (fGC) concentrations. Note, the y-axis is log-transformed, which diminishes the difference between males and females, but shows the proportional difference between populations. "Permanently captive" lynx were housed at captive institutions and had lived in captivity most, or all, of their lives. "Holding pen" lynx had been trapped from the wild, transported hundreds of miles, and housed in holding pens for ~2 months.

Figura 4. Diferencias entre machos y hembras en los niveles de glucocorticoides (fGC). Se debe tener en cuenta que el eje de las y ha sufrido una transformación logarítmica, lo que reduce la diferencia entre machos y hembras aunque muestra la diferencia proporcional entre ambas poblaciones. Los linces "en cautividad permanente" se alojaban en centros de cautividad y habían vivido toda su vida –o la mayor parte de ella–en cautividad. Los linces en "instalaciones de presuelta" fueron capturados en el medio silvestre, transportados a cientos de millas de su lugar de origen y alojados en instalaciones de presuelta durante aproximadamente dos meses.

Conclusions

Understanding the basic reproductive physiology of Canada lynx, including the degree of plasticity and the impact of environmental stressors, is critical for 1) developing successful captive breeding programmes; 2) designing sound conservation strategies and 3) understanding the reproductive limitations of this species in the face of environmental and climatic changes. While our current findings provide only a small start towards a better understanding, and numerous questions remain yet unanswered, continued study of these questions becomes even more urgent given the close relationship and physiological similarities of Canada lynx to other, even more threatened, Lynx species. All four Lynx species have been declining, with the most substantial decline being in the Iberian lynx population, which is now listed as "critically endangered" (IUCN, 2008). Given the biological and physiological similarities already evidenced, any information we can glean about the basic biology of one species may prove to be helpful in aiding conservation efforts for the other Lynx species as well.

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Reintroduction: case studies
and other aspects

REINTRODUCCIÓN: CASOS DE ESTUDIO Y OTRAS CONSIDERACIONES

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If people think that nature is their friend, then they sure don't need an enemy.

Kurt Vonnegut
(1922-2007)

Photo: KORA

Lessons from the reintroduction of the Eurasian lynx in Central and West Europe

Lecciones aprendidas a partir de la reintroducción del lince boreal en Europa Central y Occidental

Manuela von Arx, Christine Breitenmoser-Würsten and Urs Breitenmoser

Resumen

En este capítulo revisamos las reintroducciones del lince boreal *(Lynx lynx)* en Europa Central y Occidental, así como el estado actual de las poblaciones. Para ello, hemos utilizado los requisitos establecidos en la "Guía para Reintroducciones" de la Unión Internacional para la Conservación de la Naturaleza (IUCN), con el fin de evaluar los proyectos de reintroducción e identificar los indicadores que potencialmente pueden afectar al éxito o al fracaso de las reintroducciones de lince. Las primeras reintroducciones de lince boreal comenzaron en el año 1970 y continúan hasta la fecha. En cada caso, sólo se liberó a un número pequeño de linces, entre dos y 31 ejemplares por suelta. El 57% de los linces reintroducidos fueron capturados en la naturaleza, en las montañas de los Cárpatos de Eslovaquia; el 40% fueron linces nacidos en cautividad y el resto de los ejemplares fueron de origen desconocido. En la mayoría de los casos, la evaluación de los programas de reintroducción del lince boreal se ve afectada por la escasez de datos y por la falta de un seguimiento adecuado (a largo plazo); incluso, en algunos de los proyectos más recientes no se han utilizado métodos científicos apropiados para hacer un seguimiento de la evolución de los animales liberados o del grado de éxito del programa. No obstante, el estudio comparativo de los distintos proyectos nos permite sacar algunas conclusiones generales sobre los cambios de las amenazas históricas, sobre el número y origen de los animales, sobre la elección de los lugares de suelta, sobre la diseminación de información y participación del público, así como sobre el control y seguimiento de las poblaciones reintroducidas. Estos datos nos pueden proporcionar lecciones que nos sirvan para la recuperación del lince ibérico.

Palabras clave

reintroducción, lince boreal, *Lynx lynx*, Europa, evaluación, directrices

Abstract
We review the Eurasian lynx *(Lynx lynx)* reintroductions in Central and West Europe and the present status of the populations. The requirements defined by the IUCN Reintroduction Guidelines are used to evaluate the reintroduction projects and to identify important factors for successful lynx reintroductions. Reintroduction of Eurasian lynx started as early as 1970 and continues to present. In all attempts, only a small number of animals, ranging from two to 31 animals, were released. Fifty-seven percent of the animals were wild-caught in the Carpathian Mountains of Slovakia; 40% were captive-born lynx and some were of unknown origin. The assessment of the Eurasian lynx reintroduction programmes suffers from lack of information and insufficient (long-term) follow-up monitoring for most projects. Even some of the recent projects failed to apply adequate scientific methods to monitor the fate of the released animals and the success of the Programme. The comparison of the different projects however still allows for some general conclusions regarding the reversal of historic threats, number and origin of the animals, the choice of release sites, information and public involvement, and monitoring and follow-up programmes which might provide some lessons for the recovery of the Iberian lynx.

Keywords
reintroduction, Eurasian lynx, *Lynx lynx,* Europe, evaluation, guidelines

Lessons from the reintroduction of the Eurasian lynx in Central and West Europe

Manuela von Arx, Christine Breitenmoser-Würsten and Urs Breitenmoser

Introduction

The Eurasian lynx *(Lynx lynx)*, once widespread across Europe, has reached the minimum of its historic distribution during the first decades of the 20th century. Due to human persecution in addition to habitat destruction and loss of prey, the species only survived in Russia, the Carpathian Mountains, Western Balkans and in small numbers in Scandinavia and Finland. Around 1950, the general downward trend came to a halt and the autochthonous populations started to recover. Not only the ecological conditions had improved, but also the general attitude of people towards large carnivores had changed and they were granted legal protection or at least some form of controlled hunting (Breitenmoser, 1998). A natural re-colonisation of former habitats in central, southern and western Europe from remnant populations was, however, no longer possible (the lowlands between the forested mountain ranges were too heavily encroached by man).

Therefore, several lynx reintroduction attempts into suitable areas were initiated from the 1970s to present (Figure 1; Table 1). Forty years ago, nobody was aware of the various and long-lasting problems to be faced when reintroducing carnivores. First, the return of large predators provoked massive opposition from people regarding them as competitors. Then, large carnivores need extended living spaces, and no protected area in Europe is large enough to host a viable population. Finally, implementing a reintroduction programme is a difficult, expensive and long-lasting task due to the slow turnover and elusiveness of the animals, and needs long-term commitments of all partners (Breitenmoser et al., 2001). These constraints have to be taken into account when planning such a project. For a successful reintroduction many additional factors, listed in the Guidelines of the IUCN Re-introduction Specialist Group, are important, such as number, age, sex ratio and origin of the animals to be released, the choice of release sites and the duration of the project (IUCN, 1998). Finally, a sound knowledge on the species' biology (life history, ecology, behaviour, genetics) and a robust scientific surveillance of the Programme helps define and adjust the optimal strategy.

Overview and evaluation on Eurasian lynx reintroductions

From 1970 to present 14 lynx reintroduction projects in Germany, Switzerland, Slovenia, Italy, Austria, Czech Republic, France and Poland have taken place (Table 1). A total of 172-177 lynx were released. For the time being, we consider four of the projects as successful, six as a failure and four cannot be assessed yet. Many of these reintroductions were poorly prepared and documented. However, a comparison of the requirements for reintroductions, as defined in the IUCN Reintroduction Guidelines (IUCN, 1998), considering the information available, still provides important insights into the reasons for success or failure of reintroduction projects.

Reversal of threats leading to extinction

The Guidelines list as first requirement the removal of (historic) threats that lead to the extinction of the species. This condition was fulfilled in all reintroduction projects for the Eurasian lynx in regard to the ecological settings: Habitat (forests) and prey populations (roe deer) have recovered across Central and West Europe throughout the 20th century (Breitenmoser, 1998; Breitenmoser and Breitenmoser-Würsten, 2008). However, human density and traffic network are nowadays extremely high in some of these regions, both of which are considered an obstacle for the reintroduction of lynx. Increased fragmentation of the landscape, together with a biologically low dispersal potential of the species, hinders the expansion into new areas and the establishment of larger meta-populations.

One threat was only partly reversed: the negative attitude of people. Although the general public welcomes the return of the lynx, the rural population –with a less romantic view of nature– is more sceptical about predators, and important target groups such as hunters and sheep breeders strongly oppose (Hunziker et al., 2001). The last survey on the Eurasian lynx in Europe (von Arx et al., 2004) revealed illegal killing to be believed the main threat for the species. This is especially true for the reintroduced populations. Between 1996 and 2001, the yearly number of illegally killed lynx in the Bohemian-Bavarian population –where the topic has been thoroughly studied (Cerveny et al., 2002)– was seven individuals. In other reintroduced populations, cases discovered per year ranged from one to five (von Arx et al., 2004). Considering that the majority of illegal acts never become public, we can assume that this is only the tip of the iceberg. The problem goes far beyond financial and rational reasons and, to mitigate the conflict, not only public education, but also involvement of interest groups are key (see also "Information and public involvement" below).

Number and origin of animals

Although an assessment of carnivore reintroductions in general demonstrates that success is a function of the number of animals released and that wild-caught animals have a higher survival rate than captive-born candidates (Breitenmoser et al., 2001), this pattern is not entirely true for the Eurasian lynx. Normally, fewer than 20 lynx, often much less, have been released at a few sites (Table 1). One of the most successful programmes the reintroduction in Slovenia, which formed the basis of the Dinaric population, originated from only six released lynx. We do, however, not know yet whether the limited genetic variability may have a negative impact in the long-run in terms of an enhanced vulnerability to diseases or environmental changes.

Where wild-caught animals were used, they were taken from the Slovakian Carpathian Mountains, the geographically nearest autochthonous lynx population. Although carnivore projects using wild-caught animals have a higher ratio of success (Breitenmoser et al., 2001) and captive-born animals show a higher post-release mortality (Jule et al., 2008), captive-born lynx seem to adapt quite well to living in nature and catching wild prey. Two reintroduction projects, in the Kampinos National Park in Poland and in the Harz Mountains in Germany (Table 1), have used captive-born lynx. The monitoring of the population development was however so insufficient that a proper assessment is difficult (von Arx and Breitenmoser, 2004; von Arx et al., 2004). The Guidelines provide further requirements for using captive stock and state clearly that whenever wild individuals are available they should be preferred over captive ones and "if captive animals are to be used, it must be from a population which has been soundly managed, both demographically and genetically, according to the principles of contemporary conservation biology" (IUCN, 1998). Lynx used for the Kampinos and the Harz reintroductions were taken from European zoos without genetic management. They were partly inbred, partly hybrids of several subspecies.

Choice of release site

The selection of the release site is crucial. Beyond the obviously important local conditions in regard to adequate ecological resources, the geo-strategic situation of the release site is important. The reintroduction area should, on one hand, be "closed" so that animals dispersing from the release site do not risk loosing contact with conspecifics. Yet, on the other hand, the connection to neighbouring existing or potential nuclei must be considered in regard to the long-term development of the (meta-) population. While, for example, lynx released in Austria spread into different directions and were soon too far from each other to set up a socio-spatial system, natural and anthropogenic barriers helped to establish a core population in Switzerland (Breitenmoser and Breitenmoser-Würsten, 2008).

Information and public involvement

All reintroduction programmes of Eurasian lynx were controversial, but there is no correlation between short-term success and public information or involvement of stakeholders. Paradoxically, the three most successful projects, those in the North-western Alps, the Jura and in southern Slovenia, were among those with the poorest public information. Nevertheless, public relation seems to be important for the long-term acceptance of the returning predator. The recovery of lynx in Switzerland, for instance, still suffers from the fact that all releases in the 1970s were done in a very clandestine way (Breitenmoser and Breitenmoser-Würsten, 2008).

Monitoring and follow-up programme

Monitoring is an ultimate requirement for the control and the adaptive management of the Programme. Regardless of how careful a reintroduction project is planned and carried out, it will remain a stochastic endeavour with many uncontrollable parameters. The general set-up of a project is never enough to explain successes and failures; knowledge of individual fates is indispensable for a thorough assessment. A successful reintroduction programme must be an adaptive process, where a serious monitoring of all parameters allows the correction of parts of the project as it goes on.

Insufficient post-release monitoring was a deficiency in all early (and also some newer) Eurasian lynx reintroduction projects. Apart from the Vosges reintroduction and the newest project in eastern Switzerland, the fate of the released animals was not consequently surveyed. In Switzerland, a scientific follow-up of the reintroduced lynx was only established in 1980. In spite of all these shortcomings, in approximately half of the reintroduction attempts, released animals established well, reproduced and expanded their distribution range. The remaining projects, however, failed (Table 1).

Status of the established populations

At present, we distinguish between the Bohemian-Bavarian, Dinaric, Alpine, Jura, and Vosges-Palatinian populations founded through reintroductions (Table 1; Fig. 1). The last Pan-European inquiry (von Arx et al., 2004) revealed that, approximately 30 years after the reintroductions, all populations are still considered to be "Endangered" to "Critically Endangered" at a local scale, according to the IUCN/SSC Red List Criteria (IUCN, 2003). Population sizes range from 20-37 (Vosges-Palatinian) to 130 (Dinaric). To be upgraded to "Vulnerable", an effective population size of at least 250 mature individuals would be necessary. Although a surprising number of the small-scale reintroduction projects were "successful" in founding a local population, it will still require a considerable amount of time –and possibly additional efforts– to establish viable populations. However, in many cases, this will never be possible because of the limited potential expansion of some of these populations.

Photo: C. Angst

Figure 1. Release of a Eurasian lynx in Switzerland.

Figura 1. Suelta de un lince euroasiático en Suiza.

Population/ Occurrence	Location of the re-introduction	Years	Number of animals (m/f)*	Origin of animals	Fate **
Bohemian-Bavarian	Bavarian Forest (DE)	1970-74	5-10	3 wild, 2 captive	failed
	Sumava Mts. (CZ)	1982-89	18 (11/7	wild	(success)
Dinaric	Kocevje (SI)	1973	6 (3/3)	wild	(success)
Alpine	Western Swiss Alps	1971-76	12 (7/5)	wild	(success)
	Engadin (CH)	1972/80	4 (2/2)	wild	failed
	Gran Paradiso NP (IT)	1975	2 (2/0)	wild	failed
	Austrian Alps	1977-79	9 (6/3)	wild	failed
	Eastern Swiss Alps	2001-08	12 (6/6)	wild	uncertain
Alpine/Jura	Swiss Plateau	1989	3	unknown	failed
Jura	Swiss Jura Mts.	1972-75	10 (5/5)	wild	(success)
Vosges-Palatinian	Vosges Mts. (FR)	1983-89	21 (12/9)	19 wild, 2 captive	uncertain
Podyji	Podyji NP (CZ)	1993-94	6 (2/2)	captive	failed
Kampinos occ.	Kampinos NP (PL)	1992-99	31 (14/17)	captive	uncertain
Harz occ.	Harz Mts. (DE)	since 2000	28 (9/15)	captive	uncertain

* m/f= males/females. Sometimes the information is not or only partly available.
** Fate: "Success" in brackets as these populations have up to now been surviving for 20-30 years with reasonable numbers of animals, however their long-term survival is not yet secured.
* m/f= machos/hembras. En ocasiones la información no está disponible o sólo se dispone de datos parciales.
** Evolución: "Éxito", entre comillas, porque estas poblaciones llevan sobreviviendo ya entre 20 y 30 años, con un número razonable de animales; no obstante, su supervivencia a largo plazo no está asegurada todavía.

Table 1. Lynx *(Lynx lynx)* reintroductions in Central and West Europe. Data compiled from Breitenmoser et al., 2001; von Arx et al., 2004; Breitenmoser and Breitenmoser-Würsten; 2008, Linnell et al., 2009.

Tabla 1. Reintroducciones del lince *(Lynx lynx)* en Europa Central y Occidental. Datos recopilados de Breitenmoser et al., 2001; von Arx et al., 2004; Breitenmoser y Breitenmoser-Würsten; 2008, Linnell et al., 2009.

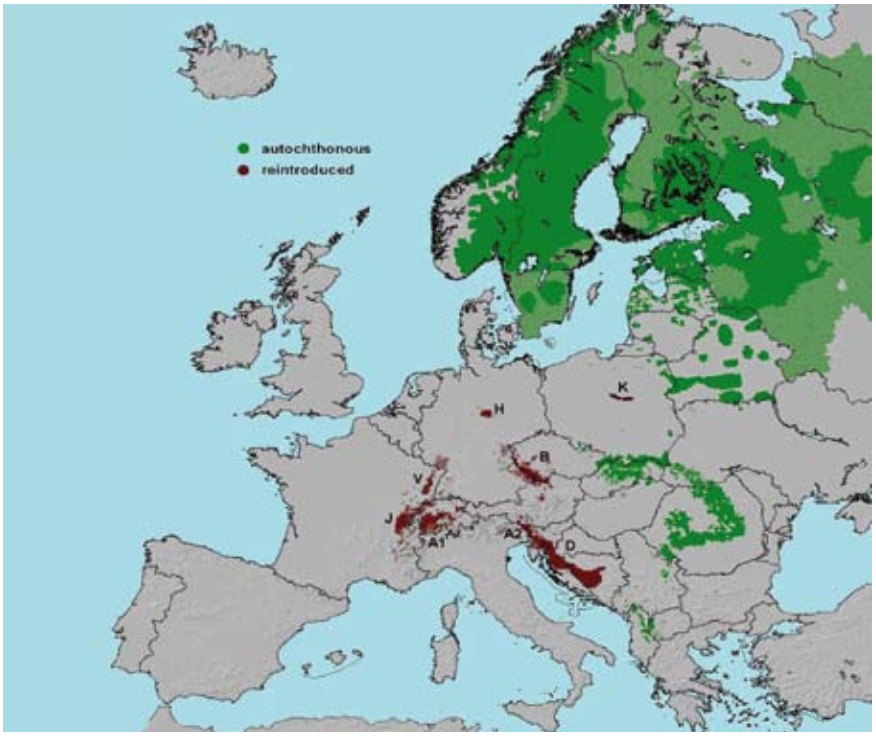

Figure 2. Distribution of the Eurasian lynx in Europe (von Arx et al., 2004). Constantly occupied area and single observations (brighter shade). Reintroduced populations: B=Bohemian-Bavarian: D=Dinaric; A=Alpine [with a western 1) and eastern 2) subpopulation]; J=Jura; V=Vosges-Palatinian; K=Kampinos occurrence; H=Harz occurrence.

Figura 2. Distribución del lince boreal en Europa (von Arx et al., 2004). Área de ocupación constante y observaciones individuales (color más claro). Poblaciones reintroducidas: B=Bohemia-Bavaria; D=Dinaric; A=Alpes [con subpoblaciónes occidental 1) y oriental 2)]; J=Jura; V=Vosges-Palatina; K=presencia en Kampinos; H=presencia en Harz.

In order to improve their conservation status, the populations in West and Central Europe should be considered under a metapopulation concept, which would involve improving the connectivity and consequently exchange of individuals between populations. As all potential or extant metapopulations are transboundary, cross-border collaboration has to be improved and coherent strategies should be developed and applied according to the European guidelines for population level management of large carnivores (Linnell et al., 2008).

Conclusions

Given the unprofessional approach in most of the Eurasian lynx reintroduction projects carried out in the 1970s and 1980s, the establishment of free-living populations was rather astonishing (Figure 2). However, the assessment of the reintroductions depends on the definition of success and the time frame applied. All populations are still small in size and extension, which makes them not only vulnerable to human-induced mortality, but also to genetic and stochastic processes. Obviously, 20 to 30 years are not enough to ensure the long-term persistence of lynx in Central and Western Europe, and further active support is needed. Even if the early attempts could not be considered brilliant and successful, they have at least allowed us to learn about the reintroduction of controversial animals such as the lynx, and to develop better schemes.

Reintroducing carnivores is a serious business that requires a long-term commitment of all partners involved, also –and especially– from government organisations (see Jiménez, this book). All these projects are controversial, and diverging interests can only be mitigated through a clear and long-term concept regarding reintroduction goals, together with a sound management strategy that grants the long-term survival of the reintroduced lynx populations.

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We have a rare opportunity here and with the help of the British Columbia trappers, we can bring back a native that has been missing from the Colorado mountains for a long time. ..... OK then. Let's do it, and let's make it work.

John Mumma,
Colorado Division of Wildlife Director
(1995-2000)

Photo: Tanya Shenk

Canada lynx *(Lynx canadensis)* reintroduction in Colorado

Reintroducción del lince canadiense *(Lynx canadensis)* en Colorado

Tanya M. Shenk, Rick H. Kahn, Gene Byrne, David Kenvin,
Scott Wait, John Seidel and John Mumma

Resumen

El lince canadiense *(Lynx canadensis)* habita en todos los bosques boreales del norte de Norteamérica y su distribución histórica más meridional se encuentra en el estado de Colorado, donde la especie campeaba en los bosques montañosos de mayor altura. A finales de los 70, los linces se habían extinguido en Colorado o sólo quedaban unos pocos ejemplares. Teniendo en cuenta el aislamiento de este estado respecto de las poblaciones más cercanas del norte, la División de Flora y Fauna de Colorado consideró que la reintroducción de la especie era la única opción para intentar restablecerla dentro de su territorio. El programa de reintroducción del lince canadiense en Colorado tiene como objetivo establecer una población viable de linces. Para valorar si el trabajo de reintroducción está teniendo éxito se utiliza la evaluación periódica de los logros alcanzados como método provisional. Consideramos que hay siete criterios necesarios para lograr una población viable: 1) creación de protocolos de suelta que impliquen una supervivencia inicial alta tras la liberación de los ejemplares reintroducidos; 2) supervivencia a largo plazo del lince en Colorado; 3) fomento de la filopatría (fidelidad al lugar de suelta) del lince en densidades suficientes para conseguir la reproducción en aquellas áreas que ofrezcan un buen hábitat; 4) los linces reintroducidos deben reproducirse; 5) la reproducción debe continuar con la reproducción de los cachorros supervivientes; 6) los linces nacidos en Colorado deben llegar a la edad de reproducción y reproducirse con éxito, y 7) la natalidad debe ser igual o superior a la mortalidad. Los primeros linces fueron soltados en Colorado en febrero de 1999. Se documentaron tanto la filopatría como la supervivencia mediante un seguimiento intensivo de los ejemplares, utilizando telemetría. La primera reproducción fue observada en la época de cría del año 2003. Las épocas de reproducción exitosa fueron documentadas en los años 2004, 2005 y 2006. La madre de una de las camadas que correspondían a la primera repoblación de linces nacidos en Colorado fue una hembra de lince nacida en Colorado en el año 2004. Hasta la fecha, los resultados han demostrado que

la División de Flora y Fauna de Colorado ha creado protocolos de suelta que garantizan una alta tasa de supervivencia inicial tras la liberación, seguida de una supervivencia a largo plazo también alta, así como la filopatría, reproducción y repoblación de linces nacidos en Colorado en la población reproductora del estado. Queda por demostrar si Colorado es capaz de fomentar un nivel de repoblación que permita compensar la mortalidad anual y, con el tiempo, obtener una población viable de linces. El trabajo de seguimiento continúa con el fin de documentar si esto puede ser viable.

Palabras clave
Colorado, lince, *Lynx canadensis*, reintroducción

Abstract
The Canada lynx *(Lynx canadensis)* occurs throughout the boreal forests of northern North America. Colorado represents the southern-most historical distribution of lynx, where the species occupied the higher elevation, montane forests in the state. Lynx were extirpated or reduced to a few animals in the state by the late 1970's. Given the isolation of Colorado to the nearest northern populations, the Colorado Division of Wildlife considered reintroduction as the only option to attempt to reestablish the species in the state. The goal of the Colorado lynx reintroduction programme is to establish a viable population of lynx in this state. Evaluation of incremental achievements is an interim method of assessing if the reintroduction effort is progressing towards success. There are seven critical criteria for achieving a viable population: 1) development of release protocols that lead to a high initial post-release survival of reintroduced animals; 2) long-term survival of lynx in Colorado; 3) development of site fidelity by the lynx to areas supporting good habitat in densities sufficient to breed; 4) reintroduced lynx must breed; 5) breeding must lead to reproduction of surviving kittens; 6) lynx born in Colorado must reach breeding age and reproduce successfully, and 7) recruitment must be equal to or greater than mortality. The first lynx were released in Colorado in February 1999. Site fidelity and survival were documented through intensive monitoring of individuals through telemetry. Reproduction was first documented during the 2003 reproduction season. Successful breeding seasons were documented in 2004, 2005 and 2006. A female lynx born in Colorado in 2004 was the mother of one of these litters which documented the first recruitment of Colorado-born lynx into the Colorado breeding population.
Results to date have demonstrated that the Colorado Division of Wildlife has developed release protocols that ensure high initial post-release survival followed by high long-term survival, site fidelity, reproduction and recruitment of Colorado-born lynx into the Colorado breeding population. What is yet to be demonstrated is whether Colorado can support sufficient recruitment to offset annual mortality for a viable lynx population over time. Monitoring continues in an effort to document such viability.

Keywords
Colorado, lynx, *Lynx canadensis*, reintroduction

Canada lynx *(Lynx canadensis)* reintroduction in Colorado

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Introduction

The Canada lynx occurs throughout the boreal forests of northern North America. Colorado represents the southern-most historical distribution of lynx, where the species occupied the higher elevation, montane forests in the state. Little was known about the population dynamics or habitat use of this species in their southern distribution. Lynx were extirpated or reduced to a few animals in the state by the late 1970's due, most likely, to predator control efforts such as poisoning and trapping. Given the isolation of Colorado to the nearest northern populations, the Colorado Division of Wildlife (CDOW) considered reintroduction as the only option to attempt to reestablish the species in the state.

A reintroduction effort was begun in 1997, with the first lynx released in Colorado in 1999. To date, 218 wild-caught lynx from Alaska and Canada have been released in southwestern Colorado. The goal of the Colorado lynx reintroduction programme is to establish a self-sustaining, viable population of lynx in this state. Evaluation of incremental achievements necessary for establishing viable populations is an interim method of assessing if the reintroduction effort is progressing towards success. There are seven critical criteria for achieving a viable population: 1) development of release protocols that lead to a high initial post-release survival of reintroduced animals; 2) long-term survival of lynx in Colorado; 3) development of site fidelity by the lynx to areas supporting good habitat in densities sufficient to breed; 4) reintroduced lynx must breed; 5) breeding must lead to reproduction of surviving kittens; 6) lynx born in Colorado must reach breeding age and reproduce successfully, and 7) recruitment must equal or be greater than mortality over an extended period of time.

The post-release monitoring programme for the reintroduced lynx has two primary goals. The first goal is to determine how many lynx remain in Colorado and their locations relative to each other. Given this information and knowing the sex of each individual, we can assess whether these lynx can form a breeding core from which a viable population might be established. From these data we can also describe general movement patterns and habitat use. The second primary goal of the monitoring programme is to estimate survival of the reintroduced lynx and, where possible, determine causes of mortality for reintroduced lynx. Such information will help in assessing and modifying release protocols and management of lynx once they have been released to ensure their highest probability of survival.

Additional goals of the post-release monitoring programme for lynx reintroduced to the southern Rocky Mountains included refining descriptions of habitat use and movement patterns and describing successful hunting habitat

once lynx established home ranges that encompassed their preferred habitat. Specific objectives for the site-scale habitat data collection include: 1) describe and quantify site-scale habitat use by lynx reintroduced to Colorado; 2) compare site-scale habitat use among types of sites (e.g., kills vs. long-duration beds), and 3) compare habitat features at successful and unsuccessful snowshoe hare chases.

Documenting reproduction is critical to the success of the Programme and lynx are monitored intensively to document breeding, births, survival and recruitment of lynx born in Colorado. Site-scale habitat descriptions of den sites are also collected and compared to other sites used by lynx.

Lynx is listed as threatened under the Endangered Species Act (ESA) of 1973, as amended (16 U. S. C. 1531 et. seq.) (U.S. Fish and Wildlife Service, 2000). Colorado is included in the federal listing as lynx habitat. Thus, an additional objective of the post-release monitoring programme is to develop conservation strategies relevant to lynx in Colorado. To develop these conservation strategies, information specific to the ecology of the lynx in its southern Rocky Mountain range, such as habitat use, movement patterns, mortality factors, survival, and reproduction in Colorado is needed.

Methods

Study area

Southwestern Colorado is characterized by wide plateaus, river valleys, and rugged mountains that reach elevations over 4200 m. Engelmann spruce-subalpine fir is the most widely distributed coniferous forest type at elevations most typically used by lynx. The Core Release Area is in southwestern Colorado (Figure 1). The lynx-established core area is in central Colorado and includes areas of continuous use by lynx, including areas used during breeding and denning (Figure 1).

Reintroduction effort

All 2006 lynx releases were conducted under the protocols found to maximize survival (see Shenk, 2001). Estimated age, sex and body condition were ascertained and recorded for each lynx prior to release (see Wild, 1999). Specific release sites were selected based on land ownership and accessibility during times of release (Byrne, 1998). Lynx were transported from the Frisco Creek Wildlife Rehabilitation Center, where they were held from their time of arrival in Colorado, to their release site in individual cages.

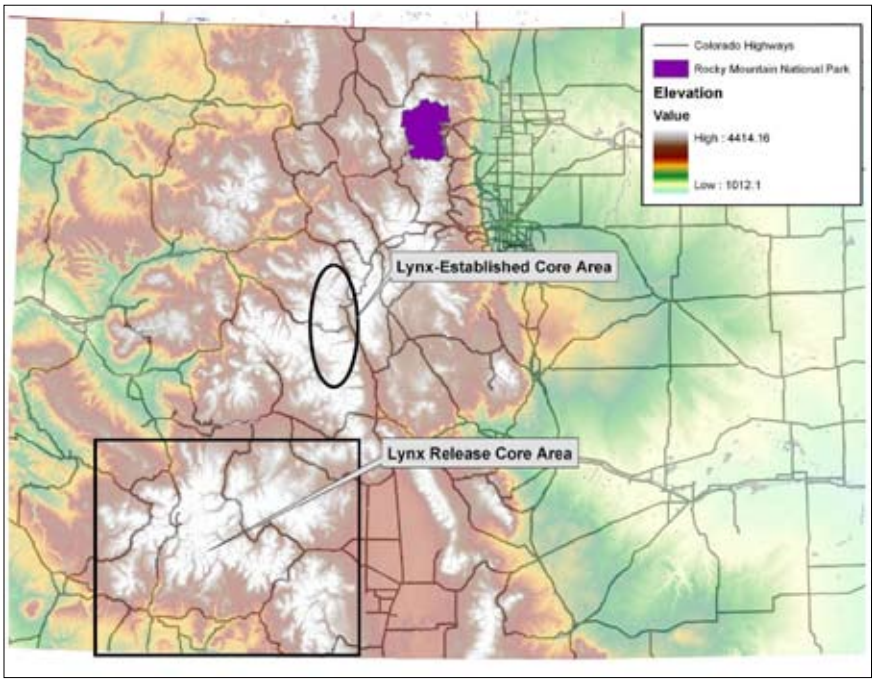

Figure 1. Lynx are monitored throughout Colorado and by satellite throughout the western United States. The lynx core release area, where all lynx were released, is located in southwestern Colorado. A lynx-established core use area has developed in the Taylor Park and Collegiate Peak area in central Colorado.

Figura 1. Se realiza un seguimiento de los linces en todo Colorado y, mediante telemetría satélite, en todo el oeste de los Estados Unidos. El corazón del área de suelta de los linces, donde fueron soltados todos los ejemplares, está situado en el suroeste de Colorado. Los linces han establecido un área vital que ha ido creciendo en la zona del Parque Taylor y Collegiate Peak en el centro de Colorado.

Distribution and movement patterns

All lynx released in 1999 were fitted with Telonics™ radio-collars. All lynx released since 1999, with the exception of five males released in spring 2000, were fitted with Sirtrack™ dual satellite/VHF radio-collars. To determine general movement patterns of reintroduced lynx, regular locations of released lynx were collected through a combination of aerial, satellite and ground radio-tracking. Locations were recorded in UTM coordinates and general habitat descriptions for each ground and aerial location were recorded.

Home range

Annual home ranges were calculated as a 95% utilization distribution using a kernel home-range estimator for each lynx we had at least 30 locations for within a year. A year was defined as March 15 – March 14 of the following year. Locations used in the analyses were collected from September 1999 – January 2006 and all locations obtained for an individual during the first six months after its release were eliminated from any home range analyses as it was assumed movements of lynx initially post-release may not be representative of normal habitat use. All locations used within a single home range analysis were taken a minimum of 24 hours apart.

Home range estimates were classified as being for a reproductive or non-reproductive animal. A reproductive female was defined as one that had kittens with her; a reproductive male was defined as a male whose movement patterns overlapped that of a reproductive female. If a litter was lost within the defined year a home range described for a reproductive animal were estimated using only locations obtained while the kittens were still with the female.

Survival and mortality factors

When a mortality signal was heard during either satellite, aerial or ground surveys, the location (UTM coordinates) was recorded. Ground crews then located and retrieved the carcass as soon as possible. The immediate area was searched for evidence of cause of death. All carcasses were transported to the Colorado State University Veterinary Teaching Hospital for a post mortem exam to 1) determine the cause of death and document with evidence; 2) collect samples for a variety of research projects, and 3) archive samples for future reference (research or forensic).

Reproduction

Females were monitored for proximity to males during each breeding season. We defined a possible mating pair as any male and female documented within at least 1 km of each other in breeding season through either flight data or snow-tracking data. Females were then monitored for site fidelity to a given area during each denning period of May and June. Each female that exhibited stationary movement patterns in May or June were closely monitored to locate possible dens. Dens were found when field crews walked in on females that exhibited virtually no movement for at least 10 days from both aerial and ground telemetry.

Kittens found at den sites were weighed, sexed and photographed. Each kitten was uniquely marked by inserting a sterile passive integrated transponder (PIT, Biomark, Inc., Boise, Idaho, USA) tag subcutaneously between the shoulder blades. Time spent at the den was minimized to ensure the least amount of disturbance to the female and the kittens. Weight, PIT-tag number, sex and any distinguishing characteristics of each kitten was also recorded. Beginning in 2005, blood and saliva samples were collected and archived for genetic identification.

During the den site visits, den site location was recorded as UTM coordinates. General vegetation characteristics, elevation, weather, field personnel, time at the den, and behavioral responses of the kittens and female were also recorded. Once the females moved the kittens from the natal den area, den sites were visited again and site-specific habitat data were collected (see Habitat Use section below).

Site-scale habitat use

Gross habitat use was documented by recording canopy vegetation at aerial locations. More refined descriptions of habitat use by reintroduced lynx were obtained through following lynx tracks in the snow (i.e., snow-tracking) and site-scale habitat data collection conducted at sites found through this method to be used by lynx.

Diet and hunting behavior

Winter diet of reintroduced lynx was estimated by documenting successful kills through snow-tracking. Prey species from failed and successful hunting attempts were identified by either tracks or remains. Scat analysis also provided information on foods consumed. Scat samples were collected wherever found and labeled with location and individual lynx identification. Only part of the scat was collected (approximately 75%); the remainder was left in place in the event that the scat was being used by the animal as a territory mark. Site-scale habitat data collected for successful and unsuccessful snowshoe hare kills were compared.

Results

Reintroduction effort

From 1999 through 2006, 218 lynx were reintroduced into southwestern Colorado (Table 1). All lynx were released in the Core Release Area of southwestern Colorado at or near previously used release sites in southwestern Colorado. Lynx were released with dual VHF/satellite radio collars so they could be monitored for movement, reproduction and survival.

Distribution and movement patterns

A total of 8680 aerial VHF locations for all 218 reintroduced lynx have been collected to date (June 30, 2006). An additional 18,963 satellite locations have been collected. Most lynx released in 2006 remained in southwestern Colorado. The majority of surviving lynx from the entire reintroduction effort continue to use high elevation (>2900 m), forested areas from New Mexico north to Gunnison, west as far as Taylor Mesa and east to Monarch Pass. Most movements away from the Core Release Area were to the north.

Numerous travel corridors have been used repeatedly by more than one lynx. Lynx appear to remain faithful to an area during winter months, and exhibit more extensive movements away from these areas in the summer. Such movement patterns have also been documented by native lynx in Wyoming and Montana (Squires and Laurion, 1999).

• Home range

Reproductive females had the smallest 90% utilization distribution annual home ranges ($\bar{x}$=75.2 km^2, SE=15.9 km^2, n=19), followed by attending males ($\bar{x}$=102.5 km^2, SE=39.7 km^2, n=4). Non-reproductive females had the largest annual home ranges ($\bar{x}$=703.9 km^2, SE=29.8 km^2, n=32) followed by non-reproductive males ($\bar{x}$=387.0 km^2, SE=73.5 km^2, n=6). Combining all non-reproductive animals yielded a mean annual home range of 653.8 km^2 (SE=145.4 km^2, n=38).

• Survival and mortality factors

As of June 30, 2006, CDOW was actively tracking 95 of the 138 lynx still possibly alive. There are 43 lynx that we have not heard signals on since at least June 30, 2005 and these animals are classified as "missing". One of these missing lynx is a mortality of unknown identity, thus only 42 are truly missing. Possible reasons for not locating these missing lynx include 1) long distance dispersal, beyond the areas currently being searched, 2) radio failure or 3) destruction of the radio (e.g., run over by car). CDOW continues to search for all missing lynx during both aerial and ground searches. Two of the missing lynx released in 2000 are thought to have slipped their collars.

Year	Females	Males	TOTAL
1999	22	19	41
2000	35	20	55
2003	17	16	33
2004	17	20	37
2005	18	20	38
2006	6	8	14
TOTAL	115	103	218

Table 1. Lynx released in Colorado from February 1999 through June 30, 2006.

Tabla 1. Linces liberados en Colorado entre febrero de 1999 y el 30 de junio de 2006.

Of the total 218 adult lynx released from 1999-2006 there are 80 known mortalities as of June 30, 2006. Causes of death are listed in Table 2. Starvation was a significant cause of mortality in the first year of releases only. Mortalities occurred throughout the areas through which lynx moved. Approximately 31.3% were human-induced which were attributed to collisions with vehicles

Cause of Death	Number of Mortalities
Unknown	26
Hit by Vehicle	11
Starvation	10
Shot	9
Other Trauma	7
Probable Shot	5
Plague	5
Predation	3
Probable Predation	2
Illness	2
Total Mortalities	80

Table 2. Causes of death for lynx released into southwestern Colorado from 1999-2006 as of June 30, 2006.

Tabla 2. Causas de la muerte de linces soltados en el suroeste de Colorado entre 1999 y 2006, (datos hasta el 30 de junio de 2006).

or gunshot. Malnutrition and disease/illness accounted for 21.3% of the deaths while 32.5% of the deaths were from unknown causes (Table 2).

Reproduction

Reproduction was first documented in 2003 when six dens and a total of 16 kittens were found in southwestern Colorado. Reproduction was also documented in 2004, 2005 and 2006 (Table 3). We weighed, photographed, PIT-tagged the kittens and recorded sex. We also took blood samples from the kittens for genetic work in an attempt to confirm paternity. While we were working with the kittens the females remained nearby, often remaining visible to us. The females generally continued a low growling vocalization the entire time we were at the den. In all cases, the female returned to the den site once we left the area. At all dens the females appeared in excellent condition, as did the kittens. The kittens weighed from 250-770 grams. Lynx kittens weigh approximately 200 grams at birth and do not open their eyes until they are 10-17 days old. Mean number of kittens per litter from 2003-2006 was 2.78 (SE=0.05) and sex ratio of females to males was equal ($\bar{x}$=1.14, SE=0.14).

The percent of tracked females found with litters in 2006 was lower (0.095) than in the three previous years (0.413, SE=0.032, Table 3). However, all demographic and habitat characteristics measured at the four dens that were found in 2006 were comparable to all other dens found. In addition, a female lynx born in Colorado in 2004 was the mother of one of the 2006 litters which documented the first recruitment of Colorado-born lynx into the Colorado breeding population.

Den sites. A total of 37 dens have been found from 2003-2006. All of the dens except one have been scattered throughout the high elevation areas of Colorado, south of I-70. In 2004, one den was found in southeastern Wyoming, near the Colorado border. Dens were located on steep ($\bar{x}_{slope}$=30°, SE=2°), north-facing, high elevation ($\bar{x}$=3354 m, SE=31 m) slopes. The dens were typically in Engelmann spruce/subalpine fir forests in areas of extensive downfall of coarse woody debris. All dens were located within the winter use areas used by the females.

Site-scale habitat use

Landscape-scale daytime habitat use was documented from 7421 aerial locations of lynx collected from February 1999-June 30, 2005. Throughout the year Engelmann spruce-subalpine fir was the dominant cover used by lynx.

Year	# Females Tracked	# Dens Found in May/June	% Tracked Females with Kittens	Additional Litters Found in Winter	Mean # Kittens/Litter	Total Kittens Found	Sex Ratio M/F
2003	17	6	0.353		2.67 (SE=0.33)	16	1.0
2004	26	11	0.462	2	2.83 (SE=0.24)	39	1.5
2005	40	17	0.425	1	2.88 (SE=0.18)	50	0.8
2006	42	4	0.095		2.75 (SE=0.47)	11	1.2
Mean			0.334 (SE=0.083)		2.78 (SE=0.05)	TOTAL 116	1.14 (SE=0.14)

Table 3. Lynx reproduction summary statistics for 2003-2006.

Tabla 3. Cifras resumidas correspondientes a la reproducción del lince durante los años 2003-2006.

A mix of Engelmann spruce, subalpine fir and aspen *(Populus tremuloides)* was the second most common cover type used throughout the year. Various riparian and riparian-mix areas were the third most common cover type where lynx were found during the daytime flights. Use of Engelmann spruce-subalpine fir forests and Engelmann spruce-subalpine fir-aspen forests was similar throughout the year. There was a trend in increased use of riparian areas beginning in July, peaking in November, and dropping off December through June.

The most common tree species documented in the site-scale habitat plots was Engelmann spruce. Subalpine fir and aspen were also present in >35% of the plots. While Engelmann spruce and subalpine fir occurred in similar densities for kills, long beds and travel sites, den sites had twice the density of subalpine firs found at all other sites.

Diet and hunting behavior

Winter diet of lynx was documented through detection of kills found through snow-tracking. Prey species from failed and successful hunting attempts were identified by either tracks or remains. Scat analysis also provided information on foods consumed. A total of 400 kills were located from February 1999-April 2005. We collected 671 scat samples from February 1999-April 2004 for content analysis. In each winter, the most common prey item was snowshoe hare, followed by red squirrel (Table 4).

A comparison of percent overstory for successful and unsuccessful snowshoe hare chases indicated lynx were more successful at sites with slightly higher percent overstory, if the overstory species were Englemann spruce, subalpine fir or willow. Lynx were slightly less successful in areas of greater aspen overstory. Higher density of Engelmann spruce and subalpine fir increased hunting success while increased aspen density decreased hunting success.

Discussion

In an effort to establish a viable population of lynx in Colorado, CDOW initiated a reintroduction effort in 1997 with the first lynx released in winter 1999. From 1999 through spring 2005, 204 lynx were released in the Core Release Area. The reintroduction effort was augmented with the release of 14 additional animals in April 2006, bringing the total to 218 lynx reintroduced to southwestern Colorado.

Locations of each lynx were collected through aerial- or satellite-tracking to document movement patterns and to detect mortalities. Most lynx remain in the high elevation, forested areas in southwestern Colorado. Dispersal movement patterns for lynx released in 2000 and subsequent years were similar to those of lynx released in 1999. However, more animals released in 2000 and subsequent years remained within the Core Release Area than those released in 1999. This increased site fidelity may have been due to the presence of con-

		Prey (%)			
Field Season	n	Snowshoe Hare	Red Squirrel	Cottontail	Other
1999	9	55.56	22.22	0	22.22
1999-2000	83	67.47	19.28	1.20	12.05
2000-2001	89	67.42	19.10	8.99	4.49
2001-2002	54	90.74	5.56	0	3.70
2002-2003	65	90.77	6.15	0	3.08
2003-2004	37	67.57	27.03	2.70	2.70
2004-2005	78	83.33	10.26	0	6.41

Table 4. Number of kills found each winter field season through snow-tracking of lynx and percent composition of kills of the three primary prey species.

Tabla 4. Número de carcasas detectadas, mediante rastreo de huellas de lince en la nieve, en distintos períodos de trabajo de campo en invierno y porcentajes de las tres presas principales que conformaban dichas carcasas.

specifics in the area on release. Numerous travel corridors have been used repeatedly by more than one lynx. Lynx appear to remain faithful to an area during winter months, and exhibit more extensive movements away from these areas in the summer. Most lynx currently being tracked are within the Core Release Area. During the summer months, lynx were documented to make extensive movements away from their winter use areas. Extensive summer movements away from areas used throughout the rest of the year have been documented in native lynx in Wyoming and Montana (Squires and Laurion, 1999). Human-caused mortality factors such as gunshot and vehicle collision are currently the highest causes of death.

Reproduction is critical to achieving a self-sustaining viable population of lynx in Colorado. Reproduction was first documented from the 2003 reproduction season and again in 2004, 2005 and 2006. Reproduction in 2006 included a Colorado-born female giving birth to two kittens, documenting the first recruitment of Colorado-born lynx into the Colorado breeding population. Additional reproduction is likely to have occurred in all years from females we are no longer tracking, and from Colorado-born lynx that have not been collared. The dens we find are more representative of the minimum number of litters and kittens in a reproduction season. To achieve a viable population of lynx, enough kittens need to be recruited into the population to offset the mortality that occurs in that year and hopefully even exceed the mortality rate for an increasing population.

Mowat et al., (1999) suggest lynx and snowshoe hare select similar habitats except that hares select more dense stands than lynx. Very dense understory limits hunting success of the lynx and provides refugia for hares. Given the high proportion of snowshoe hare in the lynx diet in Colorado, we might then assume the habitats used by reintroduced lynx also depict areas where snowshoes hare are abundant and available for capture by lynx in Colorado. From both aerial locations taken throughout the year and from the site-scale habitat data collected in winter, the most common areas used by lynx are in stands of Engelmann spruce and subalpine fir. This is in contrast to adjacent areas of Ponderosa pine, pinyon juniper, aspen and oakbrush. The lack of lodgepole pine in the areas used by the lynx may be more reflective of the limited amount of lodgepole pine in southwestern Colorado, the Core Release Area, rather than avoidance of this tree species.

In winter, hares browse on small diameter woody stems (<0.25"), bark and needles. In summer, hares shift their diet to include forbs, grasses, and other succulents as well as continuing to browse on woody stems. This shift in diet may express itself in seasonal shifts in habitat use, using more or denser coniferous cover in winter than in summer. The increased use of riparian areas by lynx in Colorado from July to November may reflect a seasonal shift in hare habitat use in Colorado. Major (1989) suggested lynx hunted the edge of dense riparian willow stands. The use of these edge habitats may allow lynx to hunt hares that live in habitats normally too dense to hunt effectively. The use of riparian areas and riparian-Engelmann spruce-subalpine fir and riparian-aspen mixes documented in Colorado may stem from a similar hunting strategy. However, too little is known about habitat use by hares in Colorado to test this hypothesis at this time.

Lynx also require sufficient denning habitat. Denning habitat has been described by Koehler (1990) and Mowat et al., (1999) as areas having dense downed trees, roots, or dense live vegetation. We found this to be in true in Colorado as well. In addition, the dens used by reintroduced lynx were at high elevations and on steep north-facing slopes. All females that were documented with kittens denned in areas within their winter-use area.

Snow-tracking of released lynx provided information on hunting behavior and diet through documentation of kills, food caches, chases, and diet composition estimated through prey remains. Snow-tracking results indicate the primary winter prey species are snowshoe hare and red squirrel, with other mammals and birds forming a minor part of the winter diet. In winter, lynx reintroduced to Colorado appear to be feeding on their preferred prey species, snowshoe hare and red squirrel in similar proportions as those reported for northern lynx during lows in the snowshoe hare cycle (Aubry et al., 1999). Caution must be used in interpreting the proportion of identified kills. Such a proportion ignores other food items that are consumed in their entirety and thus are biased towards larger prey and may not accurately represent the proportion of smaller prey items, such as microtines, in lynx winter diet. Through snow-tracking we have evidence that lynx are mousing and several of the fresh carcasses have yielded small mammals in the gut on necropsy. All evidence suggests reintroduced lynx are finding adequate food resources.

From results to date it can be concluded that CDOW has developed release protocols that ensure high initial post-release survival, and on an individual level lynx have demonstrated they can survive long-term in

areas of Colorado. It has also been documented that reintroduced lynx could exhibit site fidelity, engage in breeding behavior and produce kittens that are recruited into the Colorado breeding population. What is yet to be demonstrated is whether current conditions in Colorado can support the recruitment necessary to offset annual mortality for a population to sustain itself. Monitoring of reintroduced lynx will continue in an effort to document such viability.

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Photo: Tanya Shenk

Photo: Joe Zammit-Lucia

The tree which moves some to tears of joy is in the eyes of others only a green thing that stands in the way. Some see nature all ridicule and deformity... and some scarce see nature at all. But to the eyes of the man of imagination, nature is imagination itself.

William Blake (1757-1827)

Restoration of bobcats to Cumberland Island, Georgia, USA: lessons learned and evidence for the role of bobcats as keystone predators

Reintroducción del lince rojo en la isla de Cumberland, Georgia, EEUU: lecciones aprendidas y evidencia del papel del lince rojo como predador clave

Duane R. Diefenbach, Leslie A. Hansen, Robert J. Warren, Michael J. Conroy and M. Greg Nelms

Resumen

Entre 1988 y 1989, durante un proyecto de reintroducción, reubicamos a 32 linces rojos (*Lynx rufus*; 3,1 linces rojos/10 km^2) en una isla costera de Estados Unidos, la isla de Cumberland, en Georgia, con el fin de estudiar la reintroducción de un predador nativo. La supervivencia anual de los adultos fue del 93% (Error standard=2.6%) durante los tres primeros años. Los linces rojos recapturados tuvieron un aumento medio de peso de 0,8 kg (un incremento del 12% desde el momento de la suelta). Se documentó la reproducción de los ejemplares reintroducidos. Las presas principales fueron los conejos *(Sylvilagus palustris)*, los ciervos de cola blanca *(Odocoileus virginianus)* y las ratas de algodón *(Sigmodon hispidus)*. Entre 1997 y 1998 hubo un cambio en el tipo de presa y la presencia de ciervos y conejos en heces fue menos frecuente que la de las demás especies. Ningún lince rojo llegó a mantener un área de uso exclusivo, sin solapamiento con otros congéneres. Las estimaciones e índices de abundancia de ciervos indicaron que tras la reintroducción de los linces rojos hubo una disminución de la población de ciervos, que se mantuvo en niveles bajos, aunque el peso corporal medio de los ciervos aumentó una media de 11 kg entre 1989 y 1997. En nueve parcelas, que contenían un total de 87 robles, la regeneración de cada árbol fue medida entre 1990 y 1997; el número de árboles con plantones o brotes de raíces se incrementó de 52 a 86 y el número medio de plantones por parcela aumentó en 153,5. En aquellas parcelas que contenían plantones y brotes, tanto en 1990 como en 1997, la altura media se incrementó en 4,6 cm (95% IC=4.0–5.2). Nuestras observaciones sobre el consumo de ciervos como presa primaria de los linces rojos, la disminución de la abundancia de ciervos y la mayor regeneración del roble indicaban que los linces rojos reintroducidos causaron un efecto de cascada trófica de la isla. Los estudios previos a la reintroducción de los linces rojos indicaron que los ciervos eran abundantes y que su ramoneo impedía la regeneración de los árboles. Según los mismos estudios, los ciervos eran presas idóneas para los

linces rojos por su abundancia y su tamaño reducido. El seguimiento posterior a la suelta de una especie reintroducida proporciona información que nos permite comprender las razones por las cuales un proyecto de reintroducción pueda tener éxito o fracase. Asimismo, en los proyectos de reintroducción de poblaciones de predadores debe plantearse el posible seguimiento de las características relacionadas con los niveles tróficos del ecosistema, teniendo siempre en cuenta el escaso conocimiento que tenemos sobre el papel de los predadores en los ecosistemas, sobretodo el papel de los predadores vertebrados. Si se creasen programas de seguimiento para probar las teorías de la dinámica de las poblaciones comunitarias, habría mayores posibilidades de entender mejor las redes tróficas de los ecosistemas terrestres, así como sus interrelaciones.

Palabras clave
Predador clave, lince rojo, *Lynx rufus*, reintroducción, organización espacial, cascada trófica

Abstract
We translocated 32 bobcats (*Lynx rufus*; 3.1 bobcats/10 km^2) to a coastal barrier island, Cumberland Island, Georgia, USA, during 1988-1989 to restore a native predator. Annual survival of adults was 93% (SE=2.6%) for the first three years and recaptured bobcats exhibited an average weight gain of 0.8 kg (12% increase), and we documented reproduction. Marsh rabbits *(Sylvilagus palustris)*, white-tailed deer *(Odocoileus virginianus)* and hispid cotton rats *(Sigmodon hispidus)* were the principal prey species. By 1997-1998, prey use changed, in which white-tailed deer and marsh rabbits occurred less frequently in scats and all other species occurred more frequently. No bobcats retained areas of exclusive use from conspecifics of the same sex. Estimates and indices of deer abundance indicated that following reintroduction of bobcats the deer population declined and remained low but body weights of deer averaged 11.0 kg greater in 1997 compared to 1989. On nine plots containing 87 oak trees, where oak regeneration at each tree was measured in 1990, the number of trees with seedlings or root sprouts increased from 52 to 86 and the average number of seedlings per plot increased by 153.5. On plots that contained seedlings and sprouts in both 1990 and 1997, average height increased 4.6 cm (95% CI=4.0–5.2). Our observations of bobcat use of deer as a primary prey species, a decline in deer abundance, and an increase in oak regeneration indicated that bobcats caused a trophic cascade effect on the island. Research prior to the restoration of bobcats indicated deer were abundant and deer browsing suppressed tree regeneration, and apparently deer were suitable prey for bobcats because of their abundance and small size. Post-release monitoring of a reintroduced species provides information to understand why a reintroduction project succeeds or fails. Moreover, restoration projects of predator populations should consider monitoring trophic level characteristics of ecosystems because the role of predators in ecosystems in poorly understood, especially vertebrate predators. If monitoring programmes were developed to test theories of community population dynamics, there would be potential to better understand food webs of terrestrial ecosystems and trophic level inter-relationships.

Keywords
Food habits, keystone predator, *Lynx rufus,* reintroduction, spatial organization, trophic cascade

Restoration of bobcats to Cumberland Island, Georgia, USA: lessons learned and evidence for the role of bobcats as keystone predators

Duane R. Diefenbach, Leslie A. Hansen, Robert J. Warren, Michael J. Conroy and M. Greg Nelms

Introduction

The United States national park system is a network of nearly 400 natural, cultural and recreational sites across the nation designated to preserve and protect unique natural and cultural features. National parks designated for their natural resources have been mandated by the United States Congress to maintain the abundance, diversity, and ecological integrity of native plants and animals (16 United States Code 1, 2-4). The enabling legislation for Cumberland Island National Seashore (CINS) included directives to the National Park Service (NPS) on how the island should be managed, which included providing for public outdoor recreational use (including hunting, fishing and trapping), preserving related scenic, scientific and historic values, and conserving its primitive state together with its flora and fauna. Consequently, the Resources Management Plan for CINS (National Park Service, 1983) specifically identified extirpated species and the possibility of their reintroduction. Among extirpated predators, Harris (1984) identified the bobcat *(Lynx rufus)* as a species to receive highest priority for reintroduction because it would be least likely to cause human-related conflicts.

In 1988, the National Park Service funded the reintroduction of bobcats to Cumberland Island. However, because this project involved federal funding and public land, an Environmental Assessment (EA) was required under the National Environmental Policy Act (Public Law 91-190) to consider the environmental effects of reintroduced bobcats. We prepared the EA for the NPS (Warren et al., 1990) and justified the project from the standpoint of restoring ecological control over several species of native and exotic herbivores. We cited evidence of grazing and browsing effects from white-tailed deer *(Odocoileus virginianus)*, feral horses *(Equus caballus)*, and feral hogs *(Sus scrofa)* (Hillestad et al., 1975; Ambrose et al., 1983; Turner, 1986) and noted that bobcats can kill healthy, adult deer (McCord and Cardoza, 1982; Anderson, 1987). Furthermore, studies in the southeastern United States indicated that bobcats were effective predators on white-tailed deer fawns (Epstein et al., 1985). Other potential prey species on the island included hispid cotton rats *(Sigmodon hispidus)*, cotton deermice *(Peromyscus gossypinus)*, eastern gray squirrels *(Sciurus carolinensis)*, marsh rabbits *(Sylvilagus palustris)*, nine-banded armadillos *(Dasypus novemcinctus)*, and wild turkey *(Meleagris gallapavo)*. Of these species,

wild turkeys were not expected to be an important component of bobcat diets.

During fall of 1988 and 1989 we released a total of 32 bobcats throughout Cumberland Island. All bobcats were captured from the coastal plain of Georgia and fitted with a radio-collar to monitor post-release movements, survival, and reproduction. This translocation of bobcats to Cumberland Island afforded the opportunity to conduct a reintroduction experiment for a mid-sized felid, in which failure would have no adverse effect on the global status of the species. Furthermore, post-release monitoring provided an opportunity to study the genetics and population viability of an insular predator population, test a population monitoring technique with a known population size, monitor the social organization and spatial distribution of bobcats, study predator-prey dynamics, and monitor changes in community structure and trophic-level interactions.

In this paper we 1) identify key lessons we learned that could be useful for future felid reintroductions, 2) demonstrate the importance of post-reintroduction monitoring to learn more about the role of predators in ecosystem functioning and 3) summarize insights we have gained about bobcat prey selection and social organization in a solitary felid. Also, we present previously unpublished data we collected that provide evidence for bobcats initiating a top-down trophic cascade on the Cumberland Island forested ecosystem.

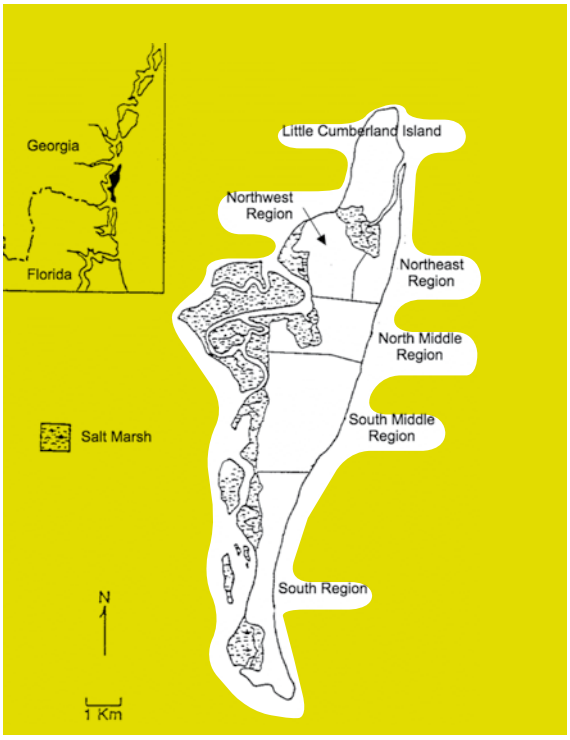

Figure 1. Location of Cumberland Island along the Georgia-Florida, USA coastline (inset) and regions of the island delineated for food habits analyses.

Figura 1. Situación geográfica de la isla de Cumberland en la costa estadounidense de Georgia-Florida (recuadro) y delimitación de las regiones de la isla para el análisis de costumbres alimentarias.

Materials and methods

Study area

Cumberland Island, a coastal barrier island 0.5 km north of the Georgia-Florida border (30°48'16"N, 81°27'36"W), is the largest among a series of barrier islands that extend along the Atlantic Ocean seaboard from Cape Hatteras, North Carolina south to Talbot Island, Florida (Figure 1). The island is 25 km long and varies in width from 1 to 6 km. It is separated from the mainland by 2–4 km of salt marsh and open water. To the north is Little Cumberland Island, which is separated from Cumberland Island by <0.25 km of salt marsh and a tidal creek.

Immediately behind the eastern shore and primary dunes of the island is an interdune meadow, ≤200 m in width, dominated by grasses, sedges, and waxmyrtle *(Myrica cerifera)*. The interior of the island is dominated by live oak *(Quercus virginianus)* and pine *(Pinus)* forests with much of the understory dominated by stands of sawtooth palmetto *(Serenoa repens)*. Freshwater wetlands follow natural depressions between former dune ridges in the interior of the islands. The western edges of the islands are salt marsh.

Cumberland Island contains five major vegetation associations covering 84.5 km^2: sandy beach and interdune meadow (14.7 km^2); maritime forest, including lowland hardwoods (38.7 km^2); scrub-shrub thickets that developed after natural fires (7.0 km^2); freshwater wetlands (6.7 km^2); and salt marsh (17.4 km^2). Little Cumberland Island is 9.0 km^2 and contains sandy beach and interdune meadow (1.3 km^2), maritime forest (4.8 km^2), and salt marsh (4.8 km^2). Hereafter, we refer to the two islands together as Cumberland Island.

The climate is warm temperate to subtropical, with normal mean temperature ranging from 12 °C in January to 28 °C in July (Johnson et al., 1974). The average annual rainfall is 134 cm, with the wettest months being June

through September ($\bar{x}$=16 cm/month) and the driest months being October, November, and April ($\bar{x}$=7 cm/month). Hillestad et al. (1975) described the study area in detail.

Capture and translocation

Details of the capture, handling, and translocation of bobcats are described in Diefenbach et al. (1993). We captured bobcats using hunting dogs *(Canis familiaris)*, foot-hold traps, and cage traps from the coastal plain of Georgia in the hope that these bobcats would have gene complexes adapted to the environment on Cumberland Island (Templeton, 1986). Captured bobcats were held in a facility for ≤1 month to monitor behavior and detect illness or injury. Only adult bobcats (≥1 year old) were reintroduced to Cumberland Island and all reintroduced bobcats were vaccinated for feline panleukopenia, rhinotracheitis, and calicivirus. Also, we held bobcats in captivity until we had 4-6 individuals to release so we could evaluate the scent-station population monitoring technique with a controlled increase in population size (Diefenbach et al., 1994).

Our goal was to release approximately 30 bobcats because this would result in a density similar to maximum densities on the mainland (1 bobcat/2.6 km^2). All releases of bobcats were "hard releases" in which bobcats were transported to the release site and freed. Release sites occurred throughout the island that were easily accessible by vehicle and likely were outside the home range of previously reintroduced bobcats.

Post-release monitoring

We began trapping on Cumberland Island to recapture bobcats a few months after the first bobcats were released on the island (Diefenbach et al., 1993). This recapture effort provided information on the physiological status of bobcats, allowed us to replace radio-collars before batteries failed, and capture bobcats born on the island to assess recruitment and survival of juveniles. We used only cage traps because they were less controversial than foot-hold traps even though they were inefficient and less effective. Captured juveniles were not vaccinated and were fitted with a radio-transmitter attached to a harness (Jackson et al., 1985) rather than a collar.

We monitored survival and locations of bobcats via triangulation of radio signals from the ground or by locating bobcats with fixed-wing aircraft throughout the year and the 24-hour day (Diefenbach et al., 2006). These data were used to assess habitat use (Baker et al., 2001; James, 1992) and spatial organization (Diefenbach et al., 2006). We monitored reproduction by conducting intensive telemetry monitoring of females during the denning season (see Ragsdale [1993] for details) to located dens and document reproduction.

To monitor food habits and prey selection we collected bobcat scats and measured prey abundance (Baker, 1991; Baker et al., 1993; Nelms, 1999; Baker et al., 2001). From November 1988 through July 1990 we surveyed prey abundance during a three-week period in November, March and July. We defined four habitats for purposes of analysis: woodlands with understories of saw palmetto (oak-palmetto), woodlands with understories not dominated by saw palmetto (open woodland), interdune meadow and an area that burned in 1981 (scrub thicket). These habitat types composed 26%, 37%, 9% and 10% of the island area, respectively, with the remainder of the island being bottomland hardwoods/shrubs, beach and residential areas.

Whenever possible, we used distance sampling methods (trapping webs or line transect surveys, Buckland et al., 2001) to estimate prey density (Baker et al., 2001). We used spotlight transects to estimate island-wide abundance of white-tailed deer and raccoons *(Procyon lotor)*. We walked eight permanent transects during early morning and late afternoon to assess habitat-specific abundance for white-tailed deer, eastern gray squirrels, nine-banded armadillos, marsh rabbits, feral swine, and raccoons. In November 1988 and March 1989 we walked each transect twice and alternated the starting point on consecutive days; four times thereafter. Each transect traversed multiple habitat types and pooled transect lengths in each habitat type were 11.5 km in oak-palmetto, 20.9 km in open woodland and 6.8 km in interdune meadow; vegetation in the scrub-thicket was too dense to observe animals. If we obtained too few observations or could not meet the assumptions of distance sampling we calculated indices of abundance (captures per 100 trap nights or numbers seen per km).

We collected bobcat scats by walking roads, trails, and dune/forest edges during a six week period encompassing each of the prey abundance surveys. Methods for identification of prey remains were described by Baker et al. (1993). Also, frequency of occurrence was estimated (no. of occurrences of a species/total

no. of scats) and diet diversity was calculated using (1 – Simpson's Diversity Index), in which greater values indicated greater diet diversity (Hall et al., 1984). We used prey abundance and bobcat diet data to examine differences in diet (prey use among species and spatial differences across the island) and changes in diet over time. Also, we tested predictions of functional relationships of bobcat diets, and if diets differed between males and females. Details of the analytical methods used are described in Baker et al. (2001).

The scat collection and analysis procedures used by Baker (1991) and Baker et al. (2001) were replicated during November-December 1997, March 1998, and August 1998 (Nelms, 1999). Seasonal diets during 1997-98 were compared with the corresponding 1988-90 data (Baker et al., 2001) using chi-square tests of homogeneity (Conover, 1980).

Trophic level changes

We used weight, sex and age data collected from deer harvested during public hunts on CINS from 1980 to 1997, in which most deer were harvested on the northern end of CINS. Because the final bobcat releases were in fall 1989, we designated the years 1980-89 as the prerelease (PRE) period and 1990-98 the postrelease (POST) period.

We aged deer via the tooth wear and replacement method (Severinghaus, 1949) except all deer estimated to be ≥4.5 years were classified as 4.5+ because of small sample sizes and greater error associated with aging older deer. Age distributions for harvested male and female deer were compared using chi-square tests for homogeneity. We conducted a nested ANOVA (PROC GLM, SAS Institute, 2003) to test for changes in mean eviscerated weight between 1984-89 and 1990-97, in which age-sex class and bobcat release period (PRE or POST) were main effects and year was nested within time period. To test the effect of bobcat release period, the mean square error for the nested year effect was the divisor for the F test. Also, we estimated the change in mean eviscerated weights for each age-sex class in the PRE versus POST periods via t-tests with means of individual years as the sample unit.

We conducted deer spotlight surveys using protocols established for CINS by Ford (1987) and modified by Baker (1991) to obtain estimates of deer density using distance sampling (Buckland et al., 2001). Deer density estimates were converted to abundance estimates assuming 6,110 ha of upland habitat. However, because deer population estimates based on distance sampling were available only for four years during 1980-98, other methods were used to obtain estimates to demonstrate population trends. We estimated annual deer abundance using hunt data with the DeLury technique (Roseberry and Woolf, 1991; Appendix I) using the number of hunters and deer kill from all hunts in each year.

Lieske et al. (1990) established plots in spring 1990 immediately following the final bobcat releases. They chose 10 sites throughout the island and at each site located 10 oak (*Q. virginiana* and *Q. hemispherica*) trees, five with associated root sprouts or seedlings and five without. A 2x4 m plot was established on opposite sides of each tree. The center line of each plot was treated as a transect, and they measured heights of the closest 10 oak sprouts and seedlings along each transect line at 0, 1 2, 3, and 4 m from the base of each tree. Seedlings and sprouts were counted in subplots but the total 16 m^2 was treated as a single sample unit. We repeated these measurements in spring 1997 at 9 of the 10 plots and conducted an ANOVA to test whether the number of seedlings and sprouts differed between 1990 and 1997 with year, plot, and tree nested within plot as explanatory variables in the model (PROC GLM, SAS Institute, 2003). We used McNemar's test to test whether the number of plots with seedlings and sprouts changed between 1990 and 1997. We used the difference in mean sprout height at each plot to calculate the change in mean sprout heights between 1990 and 1997 at each plot.

Results

The initial justification of the reintroduction for the EA, to control herbivores, was a mistake (Warren et al., 1990) because it elicited a variety of negative comments from the public. Some environmental organizations and individuals questioned whether herbivores should be controlled in national parks, whereas hunters voiced concern about bobcats preying on wild turkeys, a game species, and recommended that deer population control could be accomplished more cost-effectively using hunters. Consequently, in subsequent news releases and public meetings we emphasized the purpose of the project was to reintroduce a formerly native species to

restore biological diversity. This approach to justifying the reintroduction was successful in reducing much of the controversy, and subsequent newspaper articles de-emphasized the controversial aspects and emphasized the broader ecological significance of the project (Warren et al., 1990).

Following the public comment period, the NPS issued a Finding of No Significant Impact, which meant the project had no significant human impact and the project could move forward without further review. In hindsight, we underestimated public support for a reintroduction for its own sake, that of restoring a native predator. Had we conducted public scoping or human dimensions surveys prior to preparing the EA, we might have identified the diversity of public opinions that surrounded the proposed bobcat restoration project. Furthermore, a proactive role with the media could have minimized misconceptions about the project and resulting controversy, and personal contacts with influential people in the local community could have allowed us to identify opposition to the project prior to formally releasing the EA.

Capture and translocation

In fall 1988, we released 14 bobcats on the island (3 males, 11 females); four on 13 October, six on 3 November, and four on 28 November. Details of the capture, handling, and transporting of bobcats was described in detail by Diefenbach et al. (1993), and most aspects of this part of the project were successful. One bobcat died in captivity when it slipped its jaw through the radio-collar and suffocated; subsequently, bobcats were not fitted with a radio-collar until immediately prior to release. This resulted in additional handling of bobcats, but allowed us to assess bobcat condition immediately prior to release. Of those bobcats released in 1988, one female returned to the mainland in February 1989 and another died in January 1989, possibly due to injuries inflicted by a feral hog. In fall 1989, we released 18 bobcats (12 males, 6 females); six on 5 October, six on 25 October and six on 4 December. One male released in the interdune area swam into the Atlantic Ocean and presumably drowned.

Post-release monitoring

The effort to recapture bobcats on the island resulted in recapturing eight of 12 bobcats from the first year's release and nine of 15 bobcats from the second year's release. Thus, for the first three years of the project we knew the fate of all but one female bobcat, due to transmitter failure. Annual survival of adult bobcats was 93% (SE=2.6%, Diefenbach, 1992). Diefenbach et al. (1993) reported that most bobcats exhibited weight gains, in which bobcats increased an average of 0.8 kg (12.3%). Therefore, we have no evidence that food was limiting during this time period.

In 1989 we documented 10 kittens born in four litters, of which we monitored three from 4-10 months of age, captured and radio-collared three as adults in 1990, and recovered the carcass of one that died at two years of age. In 1990, we located one den with two kittens, and in 1991 we found no evidence that any females denned, although later in the year we observed two 3- to 4-month-old kittens. Recaptures of females for which we did not find dens with kittens indicated that they were not lactating and were unlikely to have produced young (Ragsdale, 1993).

Bobcat prey abundance differed among regions and varied seasonally, but we detected no effect of season or year on diet composition during 1989-1990 (Baker et al., 2001). On an annual basis, marsh rabbits composed the largest proportion of the diet in three of four regions of the island in both years, whereas deer composed the largest proportion of the diet in the northwest region (Baker et al., 2001). Bobcats consumed marsh rabbit, white-tailed deer, cotton rat, grey squirrel, raccoon, unidentified bird species, cotton mouse and feral hogs (Table 1). Marsh rabbit, white-tailed deer and cotton rat were the only prey species identified in bobcat diets during all surveys; thus, we considered these species the principal prey.

Only marsh rabbits (Spearman's $r=0.83$, $n=6$, $P=0.043$) and hispid cotton rats (Spearman's $r=0.84$, $n=6$, $P=0.036$) in bobcat diets were correlated with their abundance, which suggests bobcats had a functional response to these prey species. Diet species diversity (Spearman's $r=-0.87$, $n=6$, $P=0.023$) and species richness in bobcat diets (Spearman's $r=-0.82$, $n=6$, $P=0.046$) were negatively correlated with marsh rabbit abundance. This agrees with the predictions of a diet optimization model, in which increased use of alternate prey species (raccoons, feral hogs, and cotton mice) increases with decrease in abundance of a preferred prey species. Finally, changes in bobcat density or sex ratio within regions were not correlated with prey use (Baker et al., 2001), which did not support the hypothesis of interference or differences in prey use by male and female bobcats.

	November/December			March/April			July/August		
Species	1988 (n=36)	1989 (n=84)	1997 (n=86)	1989 (n=39)	1990 (n=69)	1998 (n=82)	1989 (n=64)	1990 (n=65)	1998 (n=37)
Marsh rabbit	58	43	21	64	33	22	55	39	21
Deer	47	26	12	23	38	7	44	43	31
Cotton rat	3	7	11	15	19	5	3	9	5
Grey squirrel	0	16	13	5	10	11	3	6	5
Raccoon	3	7	10	3	3	5	2	5	12
Bird spp.	3	12	11	0	15	3	5	6	2
Cotton mouse	3	11	14	3	12	23	2	3	5
Feral hog	3	5	9	3	7	24	0	0	19

Table 1. Number of scats analyzed (n) and percent occurrence of prey species in seasonal bobcat diets on Cumberland Island, Georgia, USA, 1988-90 and 1997-98.

Tabla 1. Número de excrementos analizados (n) y porcentaje de existencia de las especies de presa en las dietas estacionales de los linces rojos en la isla de Cumberland, Georgia, EEUU, durante 1988-90 y 1997-98.

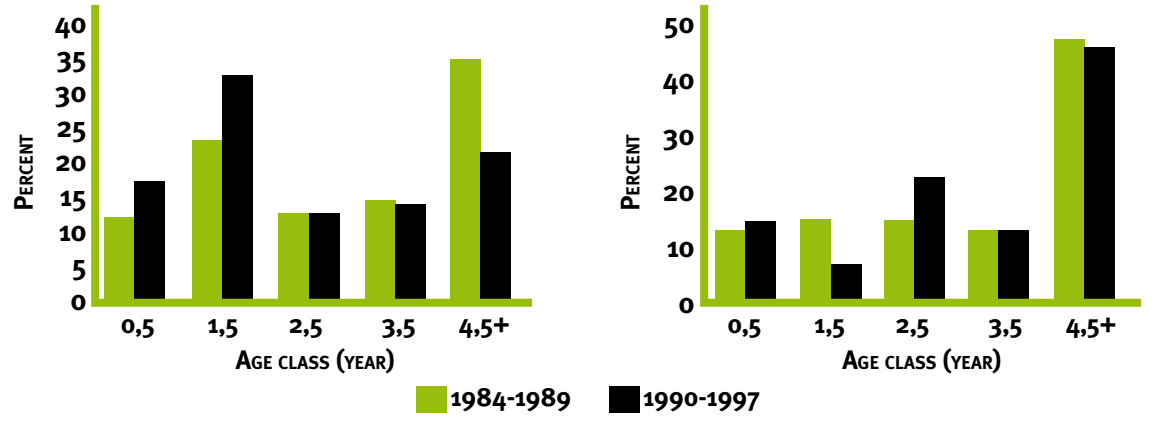

Figure 2. Age-sex structure of male (left) and female (right) white-tailed deer harvested on Cumberland Island, Georgia, USA during 1984-1989 and 1990-1997.

Figura 2. Distribución por edad-sexo de los ciervos de cola blanca capturados en la isla de Cumberland, Georgia, EEUU, durante los años 1984-1989 y 1990-1997: machos(izquierda) hembras (derecha).

We found bobcats consumed the same prey species during 1997-98, but detected important changes in prey use compared to 1988-90 (Table 1). Prey use differed in 1997-98 in fall (x^2_{14}=40.0, P < 0.001), spring (x^2_{14}=67.8, P <0.001), and summer (x^2_{14}=42.5, P <0.001). By 1997, marsh rabbit and white-tailed deer occurred less frequently in scats and occurrence of all other species increased in scats (Table 1) and this pattern was consistent among all three seasons. Overall, relative occurrence of prey species in scats was more evenly distributed during 1997-98 compared to 1988-90 (Table 1).

Female bobcats reintroduced during the first year of the reintroduction exhibited little change in the location or size of their home range, but failed to exclude newcomers from either their home range or core areas (Diefenbach et al., 2006). No bobcats retained areas of exclusive use from conspecifics of the same sex. We observed increasing intrasexual overlap among females during 1989-91, such that overlap of home ranges (95% fixed kernel utilization distributions) was equivalent to each female sharing her home range with >2 other

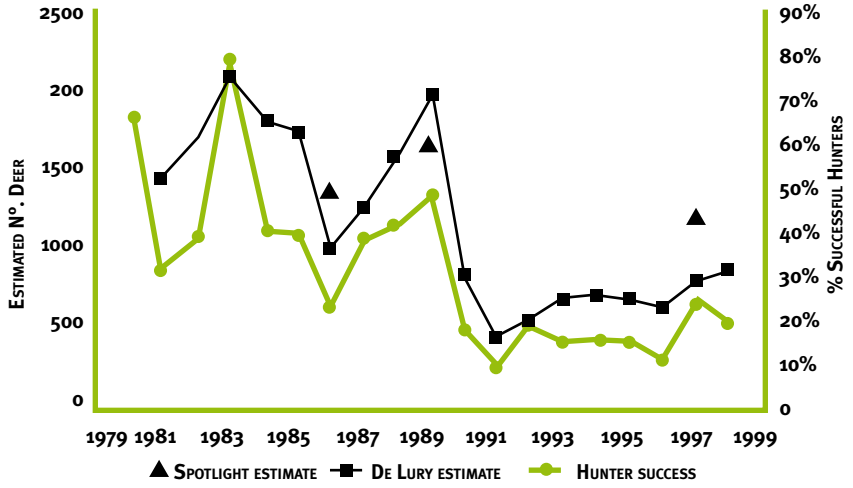

Figure 3. Population estimates (DeLury population estimate and spotlight surveys, see Methods) of white-tailed deer and an index of abundance (hunter success rate) on Cumberland Island, Georgia, USA, 1980-1998.

Figura 3. Estimaciones poblacionales de ciervos de cola blanca (utilizando el método DeLury y censos nocturnos con focos, véanse Métodos) e índice de abundancia (porcentaje de éxito de caza) en la isla de Cumberland, Georgia, EEUU, 1980-1998.

females. Overlap of core areas (50% fixed kernel utilization distributions) was equivalent to each female sharing her core area with nearly one other female.

Trophic level changes

The POST age distribution of harvested male deer was different from the PRE distribution (x^2_{14}=11.1, P=0.025), in which the proportion of fawns and yearlings increased, 2.5- and 3.5-year-old deer did not change, and 4.5+-year-old deer decreased (Figure 2). The POST age distribution of harvested female deer did not change (x^2_4=8.0, P=0.093; Figure 2). Body weights of deer increased after the reintroduction ($F_{18,819}$=100.93, P <0.001) and the effect of release period was significant ($F_{1,12}$=13.82, P=0.003). Mean eviscerated body weights increased 5.0–7.6 kg for males and 2.0–4.9 kg for females between the PRE and POST years Eviscerated body weights were 11.0 kg greater in 1997 compared to 1989 (average difference of means by age-sex class).

Estimates and indices of deer abundance indicated that following reintroduction of bobcats the population declined and remained low (Figure 3). The DeLury population estimates and hunter success rates declined following the bobcat reintroduction, even though the number of hunters during the PRE period ($\bar{x}$=270 hunters/year) differed little from the POST period ($\bar{x}$=278 hunters/year).

Of 10 plots established by Lieske et al. (1990), we re-visited nine plots and except for two trees (one dead and one not found) counted seedlings and sprouts. In 1997, 53 of 87 trees had ≥1 seedling or sprout within the 16-m² plot, but in 1990, 87 of 88 plots had ≥1 seedling or sprout (McNemar's test, x^2_1=33.0, P <0.001). The ANOVA indicated the overall F statistic was significant ($F_{87,88}$=3.44, P <0.001), the number of seedlings on plots increased an average of 153.5 between 1990 and 1997 ($F_{1,87}$=39.04, P <0.001) and we detected no differences among plots ($F_{8,79}$=0.64, P=0.742).

Discussion

We were able to successfully capture and translocate approximately 15 bobcats per year, and the complete reintroduction was completed in a short period of time and at low cost. Diefenbach et al. (1993) identified three important factors that reintroduction efforts should consider: 1) the source and genetic relatedness of individuals, 2) the age-sex structure of restored populations and 3) the method of releasing translocated individuals.

We captured bobcats from throughout the coastal plain of Georgia to obtain bobcats with gene complexes adapted to regional environmental conditions (Templeton, 1986), although multiple bobcats were captured from the same area. Consequently, some bobcats may be closely related genetically and may result in significant genetic founder effects on the population. We collected genetic samples (blood) from all bobcats, but these samples have not been analyzed. However, the opportunity exists to investigate the genetic changes in the population over time, which should be a priority of restoration efforts of an endangered species.

Photo: Duane Diefenback

Figure 4. Leslie Hansen releasing a bobcat on Cumberland Island.

Figura 4. Leslie Hansen liberando a un bobcat en la isla de Cumberland.

We were not able to capture enough bobcats on the mainland to control the sex ratio of the population of reintroduced bobcats. Consequently, at the conclusion of the translocations in 1989 the reintroduced population consisted of 14 males and 15 females, although it was female-biased (11 females, 3 males) after the translocations in 1988. These changes in the sex ratio of the population introduced potential confounding effects when interpreting results of our post-release monitoring of food habits and spatial organization (Baker et al., 2001; Diefenbach et al., 2006). Obviously, reintroductions of an endangered species should take greater care in the age-sex structure of the reintroduced population as well as the genetic relatedness of individuals.

We strongly recommend that reintroduction projects establish a means of conducting "slow-releases" whereby animals are held in captivity at the release site and allowed to leave captivity following a holding period. We believe that slow releases might have prevented the disorientation of the one bobcat that swam into the Atlantic Ocean and presumably drowned. However, the logistics of such an effort for our project were prohibitive (Diefenbach et al., 1993). We do not believe hard releases are justified in most reintroduction situations; for example, Brocke et al. (1991) reported movements of hundreds of kilometers for Canada lynx *(Lynx canadensis)* reintroduced to the Adirondacks in New York, USA.

Post-release monitoring is critical to evaluating the success or failure of a reintroduction project. We believe monitoring the physiological condition of animals after release and monitoring their movements, spatial distribution, survival and reproduction should be a mandatory aspect of any reintroduction effort. Future efforts to restore native species should endeavor to increase our knowledge about the effects of spatial distribution, genetics, demography, population size, mechanisms of population regulation, behavior and environmental conditions on the viability of populations. Most of our post-release monitoring occurred within three years of the reintroduction, which may not have been long enough to detect important changes in the bobcat population or its effects on the island. In their evaluation of prey selection, Baker et al. (2001) noted "Further studies of prey abundance and prey use…are needed to determine the long-term effect of the bobcat reestablishment on the island's fauna". To a great extent, research by Nelms (1999) conducted eight years post-reintroduction provided important insights into the effect of bobcats on the island ecosystem.

A 14-fold population decline in marsh rabbits, caused by above-normal rainfall from a hurricane, allowed us to detect changes in bobcat diets and identify a functional response to prey abundance and evidence for diet optimization (Baker et al., 2001). The frequency of occurrence of deer in bobcat diets year-round (23–47%) was greater than reported for other studies in the southeastern United States (0–8%; Maehr and Brady, 1986). Although we did not have sufficient data to identify the shape of these functional relationships, bobcat diets in 1997-1998 had lower occurrence of marsh rabbits and deer and a more even distribution of occurrence of all prey species in their diet (Table 1). Also, there was no evidence the frequent occurrence of deer in the diet was

Photo: Duane Diefenbach

Figure 5. Interdune meadow and maritime forest of Cumberland Island (and Atlantic Ocean).

Figure 5. Pradera interdunar y bosque marítimo en la isla de Cumberland (con el océano Atlántico de fondo).

because of a lack of food availability because bobcat survival was high, recaptured bobcats exhibited weight gains and bobcats maintained normal home range sizes (Diefenbach et al., 1993, Diefenbach et al., 2006).

Observation of the spatial organization of bobcats was consistent with the hypothesis that bobcats maintain home ranges via a system of land tenure established by prior rights (Diefenbach et al., 2006). However, we observed significant intrasexual overlap of both home ranges and core areas. Furthermore, we observed declining reproduction with an increase in home range overlap. Similarly, Lembeck and Gould (1979) observed a negative relationship between population density and reproduction, in which they reported 100% of females produced young when population densities were least and only 50% produced young when densities were greatest. We believe that successful reproduction in bobcats may be related to access by females to exclusive use areas even under conditions of adequate or good food availability. Under the conditions of this study (moderate bobcat density, adequate food availability and limited dispersal) bobcats exhibited no evidence of an ability to exclude other adult individuals from their home ranges or core areas. Given the inverse relationship Diefenbach et al. (2006) observed between home-range overlap and reproduction, we suggest that establishment of exclusive use areas by females may be important for successful reproduction, and that the social conditions necessary for maintaining these exclusive areas are less likely to occur at greater population densities or in the absence of dispersal opportunities, thereby reducing population productivity even without food limitation.

Previous researchers noted the adverse effects of grazing and browsing by feral horses, white-tailed deer and feral hogs (Hillestad et al., 1975; Ambrose et al., 1983; Turner 1986; Miller 1988). Bourdeau and Oosting (1959) reported live oak seedling densities of 0.28 seedlings/m^2 on Smith Island, North Carolina, USA and noted "the understory and shrub layers were very dense," whereas Hillestad et al. (1975) reported a seedling density of 0.055 seedlings/m^2 on CINS. Eight years after bobcats were reintroduced to CINS, we estimated an oak seedling density of 0.76 seedlings/m^2 on the same plots that Lieske et al. (1990) noted seedlings were rare or absent. We believe the changes we observed in oak regeneration are related to a decline in the abundance of white-tailed deer.

Consequently, our observations of bobcat use of deer as a primary prey species following their reintroduction, a decline in deer abundance, and an increase in oak regeneration suggest that bobcats caused a trophic cascade effect on the island. We did not expect to observe such strong trophic level changes on the island ecosystem because deer generally are not considered primary prey for bobcats (Maehr and Brady, 1986; but see Epstein et al., 1985). However, deer on CINS were suitable prey for bobcats because of their abundance and small size.

A keystone species is defined as one whose abundance is relatively low but whose effect on the ecosystem is relatively large (Power et al., 1996), and there are few examples of mammals as keystone species (Estes, 1996). McLarin and Peterson (1994) documented changes in vegetation via wolf *(Canis lupus)* predation on moose

(Alces alces), but there are few examples of trophic cascades involving mammalian predators, herbivores, and plants in terrestrial ecosystems (Shurin et al., 2002). We believe bobcats on CINS act as keystone predators. Given that Breitenmoser and Haller (1993) reported deer populations declined following a reintroduction of European lynx *(Lynx lynx)*, and our evidence of a trophic cascade caused by bobcats on CINS, any restoration of a felid population should consider trophic cascade effects as a real possibility.

In conclusion, we believe our research on bobcats on CINS provides strong justification for post-release monitoring of a reintroduced species. Not only does post-release monitoring provide data to better understand why a reintroduction project may have succeeded or failed, but it also can provide fundamental knowledge regarding population and community dynamics. In general, the role of predators in ecosystems is poorly understood, especially vertebrate predators (Shurin et al., 2002), and restoration projects of predator populations should consider monitoring trophic level characteristics of ecosystems. If such a monitoring programme were developed to test theories of community population dynamics, there would be potential to better understand food webs of terrestrial ecosystems and trophic level inter-relationships.

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Cierro, con un rápido paseo de retorno, el largo álbum desdoblado, saco la cabeza por el último cuadro, y me pongo, deslumbrado, a proyectar mi futuro en el ocaso.

Juan Ramón Jiménez
(1881-1958)

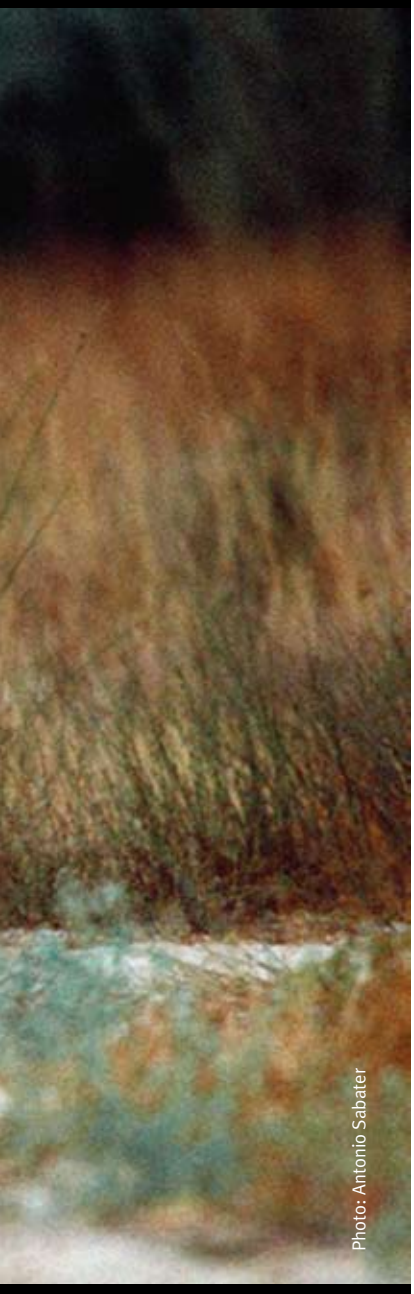
Photo: Antonio Sabater

Considerations for planning Iberian lynx translocations into Doñana National Park

Consideraciones para la planificación de la translocación de lince ibérico en el Parque Nacional de Doñana

Francisco Palomares

Resumen

El lince ibérico *(Lynx pardinus)* es la especie de felino más amenazada en el mundo. Una de las poblaciones supervivientes de lince ibérico más conocida se encuentra en el Parque Nacional de Doñana y en sus alrededores, en el entorno natural más protegido que existe dentro del área de distribución histórica de esta especie. En este lugar, el lince ibérico se ha mantenido estable durante los últimos 50 años, con una población de entre 40 y 50 ejemplares, la mayoría de los cuales vive actualmente fuera de los límites del parque. Por esta razón, la población de linces de Doñana es especialmente vulnerable a la extinción. Si dentro del parque nacional desapareciese un solo territorio de lince más, esta población podría extinguirse en los próximos 15 años. La recuperación de las áreas fuente de reproducción dentro de Doñana, además de la translocación de algunos ejemplares procedentes de Sierra Morena, así como la restauración de su hábitat y la mayor capacidad de carga de las áreas fuente dentro del parque nacional, reducirían la probabilidad de extinción de toda la metapoblación de linces de Doñana por debajo del 5% en los próximos 100 años. En este capítulo se tratan las consideraciones específicas a tener en cuenta en la selección de áreas para la translocación de linces ibéricos dentro del parque nacional, así como las características biológicas de los candidatos para la reintroducción (edad y estado del ejemplar) y las fechas más adecuadas para que ésta tenga lugar.

Palabras clave

Lince ibérico, reintroducción, extinción, Doñana

Abstract
The Iberian lynx *(Lynx pardinus)* is the most highly endangered felid species in the world. One of the best known surviving lynx populations lives in and around Doñana National Park, within the most highly protected natural setting left of the lynx's historic distribution. The population has remained stable at around 40-50 individuals for the past 20-25 years, the majority of which presently live outside Park boundaries. This makes the Doñana lynx population particularly vulnerable to extinction. If one more lynx territory disappears inside the National Park, model results indicate that extinction of the Doñana lynx population could happen within the next 15 years. Recovery of the reproductive source areas inside the national park, coupled with the translocation of a few lynxes from the Sierra Morena population, and supported by the restoration and increased carrying capacity of the source areas inside the park, would reduce the probability of extinction of the entire Doñana lynx metapopulation to below 5% in the next 100 years. In this chapter we discuss specific considerations for the selection of areas for Iberian lynx translocation inside the national park, together with the biological characteristics of translocation candidates (lynx age and status) and best timing for the actual translocation.

Keywords
Iberian lynx, translocation, extinction, Doñana

Photo: Antonio Rivas

Considerations for planning Iberian lynx translocations into Doñana National Park

Francisco Palomares

Introduction

The Iberian lynx *(Lynx pardinus)* is the most threatened felid in the world (Novell and Jackson, 1996). Endemic to the Iberian Peninsula, at present only 200 individuals remain in two populations (Doñana and Sierra Morena) of the south of Spain (Palomares et al., 2002; Guzmán et al., 2004; Simón, this book; Calzada, this book). The Doñana population, the smallest of the two, with about 40-50 lynx distributed in different nuclei over an area of approximately 2 500 km^2, is the best known and it is located in a protected area, the most sheltered from human influence when considering the present and potential distribution area of Iberian lynx in Spain and Portugal. Nevertheless, although the Doñana population has remained almost stable from the last decades, the spatial location of lynx has changed thoroughout the last 20 years. While in the late 80's most lynxes were settled inside the national park (Palomares y col., 1991), presently most of them roam outside the protected area (Román et al., 2006). This is particularly important for the viability of the Doñana population since nuclei from inside the national park act as sources for the overall population, whereas nuclei outside the protected area are sink areas for the species (Gaona et al., 1998).

Spatially explicit models indicate that viability of the current Doñana population is very low. There is a 95% probability of extinction in the next 100 year, and average extinction time could be in 32 years. Thus, if a single territory is lost inside the national park, extinction could take place in only 15 years (Revilla et al., 2007). Nevertheless, from a demographic standpoint, increasing the source populations (i.e., those inside the national park) thorough the translocation of four lynx in two years –at a rate of two lynx per year– or 10 lynx in five years –also at a rate of two lynx per year–, extinction probabilities for the Doñana population in the next 100 years would be less than 4% and 1%, respectively (Revilla et al., 2007).

On the other hand, genetic health of the Doñana lynx population is poor (Jiménez et al., this book; Meli et al., this book; López et al., this book). The first cue is that during the last decades the pelage of lynx from Doñana has lost two spot patterns, and now only lynx with large spots are found (Beltrán and Delibes, 1993). Furthermore, recent genetic studies indicate that the Doñana population has a 30% lower genetic variability than the lynx from the other remaining lynx population in Sierra Morena (Johnson et al., 2004; Godoy, this book). Breeding among close relatives (sibling, father-brother) is not unusual within the Doñana population (F. Palomares et al., unpubl.).

Therefore, there are both demographic and genetic reason to urgently translocate lynx into the source nuclei of the Doñana population. Here we present some basic considerations to help in the decision-taking process, regarding where to translocate lynx into the Doñana area. Such considerations also include indications regarding ecological and behavioural traits of the lynx, which might affect the results of the translocation.

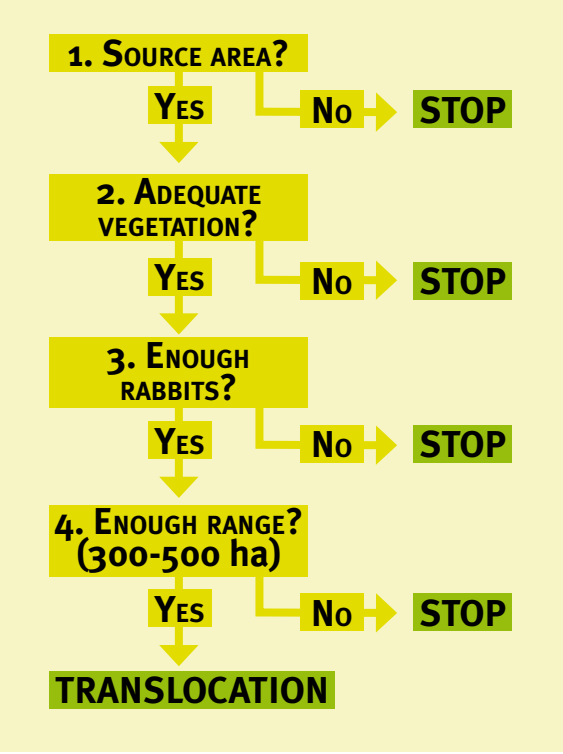

Figure 1. Hierarchy tree portraying conditions needed to be met to carry out an Iberian lynx translocation programme in the Doñana area.

Figura 1. Arbol de jerarquías mostrando las condiciones necesarias para llevar a cabo un programa de translocación de lince ibérico en Doñana.

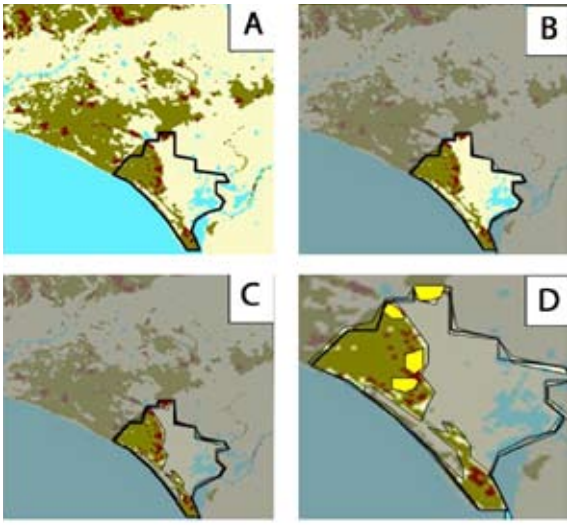

Figure 2. (a) Map of the study area showing the limits of the Doñana National Park (black line), and matrix (yellow), dispersing (green), and reproductive (red) habitats for lynx in the Doñana area; (b) Source areas (non-shadowed areas); (c) Suitable vegetation area (non-shadowed areas), and (d) Adequate areas for rabbits (yellow areas).

Figura 2. (a) Mapa del área de estudio mostrando los límites del Parque Nacional de Doñana (línea negra), y los hábitats de matriz (amarilla), dispersión (verde) y reproducción (rojo) en el área de Doñana; (b) áreas fuente (áreas no sombreadas); (c) Áreas de vegetación adecuada (áreas no sombreadas), y (d) áreas adecuadas para conejos (áreas en amarillo).

Considerations to carry out lynx translocations in Doñana

Where to translocate lynx: spatial and habitat conditions

Some basic ecological and metapopulation conditions should be met to carry out lynx translocation in Doñana (Figure 1). These conditions are, in order of importance, that the area 1) should be a potential ecological source (i.e., where natality surpasses mortality); 2) should have adequate vegetation structure; 3) should have enough rabbit, and 4) should present enough adequate habitat to accommodate at least to a couple of reproductive lynx. Specific details for the justifications of these factors can be found in Gaona et al. (1988), Ferreras et al. (2001), Palomares (this book) and references therein, but briefly are justified because lynx are specialized in the use of Mediterranean scrubland, they prey on European rabbits *(Oryctolagus cuniculus)*, and hold home ranges of at least 300 ha for areas of best habitat quality. Thus, if lynx are not living in a potential source area –with the above mentioned characteristics– even if we increase the number of individuals, it will have no net effect on metapopulation viability.

In the Doñana area, the only part with the potential to be a source is the protected area inside the national park (Figure 2). There is adequate vegetation in approximately 22 000 ha out of the 55 000 ha that comprise the national park (Figure 2). However, of these 22 000 ha, there are enough rabbit for lynx in only four patches, which altogether represent approximately 2 500 ha (Figure 2). Therefore, at present, translocations should be carried out in these areas if other lynx are not occupying them.

An additional consideration to bear in mind is that only those prime habitat patches located in the south of the national park have the potential to be expanded as a source area, provided that adequate habitat management is undertaken to recover rabbits. Therefore, these patches should be considered first when thinking about potential sites for lynx translocation in Doñana.

Lynx origin

To account for both demographic and genetic aspects, translocated lynx should stem from the Sierra Morena population. However, from a demographic point of view re-locations of individuals from the Doñana population that live in sink nuclei, or surplus individuals from other areas within the Doñana area source nuclei, would also be considered. Nevertheless, Sierra Morena individuals are preferable for this conservation management strategy.

Lynx age and sex ratio

Both adult males and females are intrasexually territorial, and males may overlap several females within their territories (Palomares, this book). Therefore, males might quickly include released females into their territories. If male lynx are also released into recipient patches with resident adult males, then there is a high probability that released males might have to move away due to competitive interactions with resident males.

Therefore, there are three questions that needed to be address in order to provide recommendations regarding this point. First, we need to know if there are any lynx in the recipient area. If not, at least one male and one female (depending of the available range) of any age-class should be released. Another possible scenario is that there is presence of adult males; in such case young or adult females should be released. And finally, if there is no adult male in the recipient area, young or adult lynx of both sexes could be released.

Season for translocations

If adult male or female are going to be released, timing for translocation should be scheduled for several months before mating (September-October). This strategy will ensure that both lynx become familiarized with the new environment before the onset of breeding season and that they also have the opportunity to make contact with other adjacent lynx. This is particularly important if animals are coming from Sierra Morena. If released lynx are re-located from other areas of Doñana, release could take place as late as December, closer to mating season, since they are already acclimated to the Doñana environment. Mating normally occurs in December-January (Palomares, this book). However, if translocated lynx have not attained reproductive age (<3 years old), releases should take place out of breeding season in order to prevent strong competitive interactions with other resident lynx.

Translocation methods

The two main methods of releasing carnivores include soft and hard release. Soft release involves a variable pre-conditioning period in the recipient area before releasing the target species. In contrast, hard release consists on releasing animal directly into the recipient area without any previous acclimatization phase. If lynx to be released are from Sierra Morena, soft release is recommended, since both landscape and weather are rather different between Sierra Morena and Doñana. If lynx to be released are re-located from other Doñana areas, hard release might be attempted, particularly if dispersing individuals are going to be used, since ecological factors will be identical.

Final considerations

Individuals to be released should be in perfect health and body condition. Therefore, a thorough health check up should be carried out before releasing the animal into Doñana (Ryser, this book). Furthermore, there is information on the presence of some parasites in the Sierra Morena population that are absent in the Doñana population (Millán et al., 2007; Meli et al., this book), and although the effect on Doñana lynx is not clear, introduction on new parasites into a "clean" population should be avoided when possible.

On the other hand, the genetic characteristics of lynx could also be considered (Fernández et al., this book) as some individuals might be more suitable than others to address the genetic problem of the Doñana population. Thus, lynx from Sierra Morena with alleles that are absent in Doñana might be more adequate for translocation than animals with a similar genetic structure as that of the Doñana population. Finally, rigorous post-release monitoring and a sound scientific study should be undertaken to help with the decision making process at least during the first years of the Programme. Therefore rigorous information on factors affecting the success or failure of the translocation programme should be quickly incorporated and analyzed at all stages of the process.

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Photo: Antonio Sabater

Todo lo que yo hago es una gota en el océano
así de pequeño es lo que podemos hacer, y
sin embargo,
si yo no lo hiciera
al océano le faltaría una gota.

Federico García Lorca
(1898-1936)

Photo: E. Abad

Short communication on the first Iberian lynx translocation from Sierra Morena to the Doñana population

Comunicación breve sobre la primera translocación de un lince ibérico de Sierra Morena a la población de Doñana

Gema Ruiz, Marcos López, Leonardo Fernández, Juan Antonio Franco, Guillermo López and Miguel A. Simón

Resumen
Esta comunicación breve tiene la finalidad de relatar la primera translocación de un lince ibérico al Parque Nacional de Doñana. La meta de esta medida de manejo fue el reforzamiento genético, para lo que se seleccionó un macho adulto de la población de Sierra Morena. La liberación se planteó en un núcleo de Doñana donde todos los ejemplares adultos eran hembras, debido a la muerte o retirada de todos los machos residentes tras un brote del virus de la leucemia felina (FeLV) que tuvo lugar en la primavera de 2007. Este suceso promovió un manejo de crisis cuya finalidad fue abordar los tres siguientes objetivos: 1) Asegurar que las tres hembras establecidas en el área de suelta no se dispersasen de la zona en búsqueda de un macho; 2) Evitar una disminución en la productividad global de la población de Doñana; 3) Evitar que aumentara la probabilidad de extinción a corto plazo de la población de Doñana. El macho seleccionado, conocido como *Baya*, fue ubicado en una instalación de presuelta en diciembre de 2007 y liberado en enero de 2008. *Baya* se apareó con las tres hembras residentes y tuvo un total de ocho cachorros mixtos (mezcla de genes de Sierra Morena y Doñana), los cuales se consideran importantes para aumentar la variabilidad genética de la población de Doñana. Seis meses tras su liberación, el área de campeo de *Baya* continuó solapándose con los respectivos territorios de las tres hembras residentes y, por tanto, su asentamiento en la zona se consideró un éxito.

Palabras clave
Translocación, instalaciones de presuelta, extinción, liberación, área de campeo, diversidad genética

Abstract
This short communication aims at describing the first translocation of an Iberian lynx into Doñana National Park. The purpose of this management approach was to help increase the genetic diversity of the Doñana population and, for this reason, we selected a specific male from the Sierra Morena population. The aim was to release this male in a nuclei where all the territorial lynxes were females –because an outbreak of Feline Leukemia (FeLV) that took place in the in the Spring of 2007 had killed all the territorial males in that area. Altogether, the goals of this crisis management approach were threefold: 1) To ensure that the three established females would not leave the core population in the process of searching for a mate; 2) To avoid a decrease in global productivity within the Doñana population; 3) To avoid augmenting the potential probability of short-term extinction in the Doñana population. The new male, known as *Baya*, was translocated into an acclimatization pen in December 2007 and released in January 2008. *Baya* mated with the three resident females during breeding season and produced eight offspring of mixed Sierra Morena-Doñana origin, which are considered important to increase the genetic diversity of the Doñana population. Six months after release, *Baya's* homerange still overlapped the respective territories of the three resident females and the male was considered to be successfully settled in the area.

Keywords
Translocation, acclimatization pen, extinction, release, homerange, genetic diversity

Photo: E. Abad

Short communication on the first Iberian lynx translocation from Sierra Morena to the Doñana population

Gema Ruiz, Marcos López, Leonardo Fernández, Juan Antonio Franco, Guillermo López and Miguel A. Simón

Introduction

The first translocation of an Iberian lynx into Doñana, which took place in December 2007 under the framework of the LIFE Nature Project (Simón et al., this book), had the purpose of strengthening this remnant population from a genetic and a demographic point of view. Even though the original restocking project was scheduled to take place in a different part of the Protected Area, a crisis management decision led to reconsider the initial translocation site and opt for releasing this valuable male into the Coto del Rey nuclei, where a Feline Leukemia (FeLV) outbreak had wiped out the four territorial males in the area (López et al., this book).

The purpose of this crisis management decision was three-fold:

1) To ensure that the three established females would not leave Coto del Rey in the process of searching for a mate.

2) o avoid a decrease in global productivity within the Doñana population, which would result if the Coto del Rey metapopulation would not have adult males to breed with the established, territorial females.

3) To decrease the potential for short-term extinction in the Doñana population.

Population models predicted that the loss of a single territory in Coto del Rey would increase by 10% the global probability of extinction of the Doñana Iberian lynx population (Palomares et al., this book). Natural re-colonization of the Coto del Rey nuclei by free-ranging males was hard to predict but, in all likelihood, given the scarcity of adult males in Doñana, the most probable scenario would have been the settlement of a juvenile male, with lower reproductive potential than that of an adult. In fact, this has proven to be the case, since only one subadult male has naturally recolonized the area after the FeLV outbreak took place.

The translocation of lynxes from Sierra Morena to Doñana was originally thought out as a means to increase the already diminished genetic variability of this population. After the FeLV outbreak, the need for re-stocking was not only genetic, but also demographic. The situation encountered after the loss of all territorial males in Coto del Rey left three breeding females available in Doñana's main "population source" (Palomares et al., this book) which, paradoxically, was a situation that would allow for a more rapid gene flow of Sierra Morena genes through the Doñana population.

Pre-release considerations

The male selected for translocation, *Baya*, belonged to the 2005 cohort. One of the selection criteria included that the animal would be *Cytauxzoon*-free, since no *Cytauxzoon* has ever been detected in the Doñana free-ranging population (Meli et al., this book). After a 6-week quarantine period that ensured that *Baya* was disease-free, he was transferred to an acclimatization pen in Coto del Rey. *Baya's* translocation took place on December 21st, 2007, via soft-release in a 2

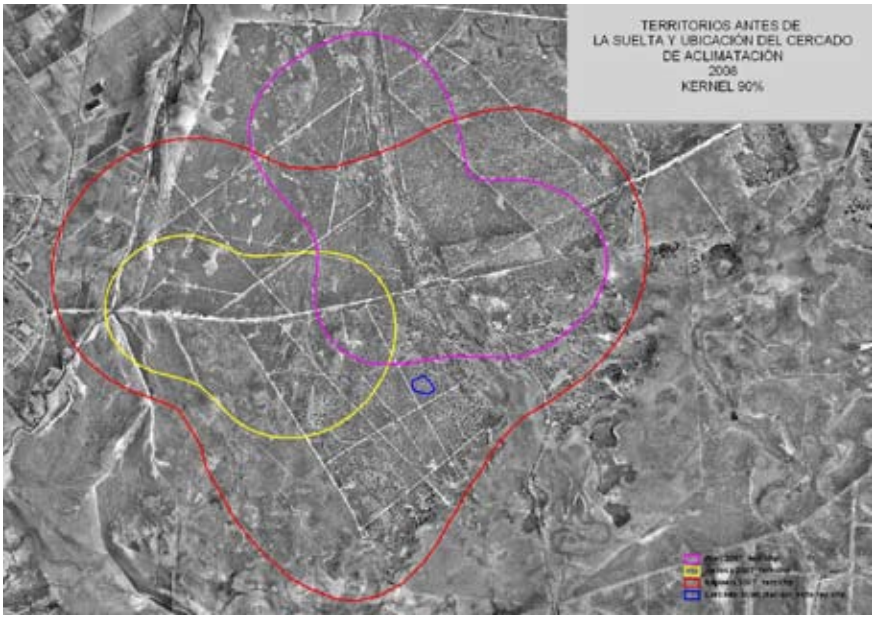

Figure 1 (a). Territories of the resident breeding females (red, blue and green). The arrow indicates the placement of the acclimatization pen, which is represented by an orange square.

Figura 1 (a). Territorios de las hembras reproductoras residentes (rojo, azul y verde). Con una flecha se indica la ubicación del cercado, que aparece representado esquemáticamente en color naranja.

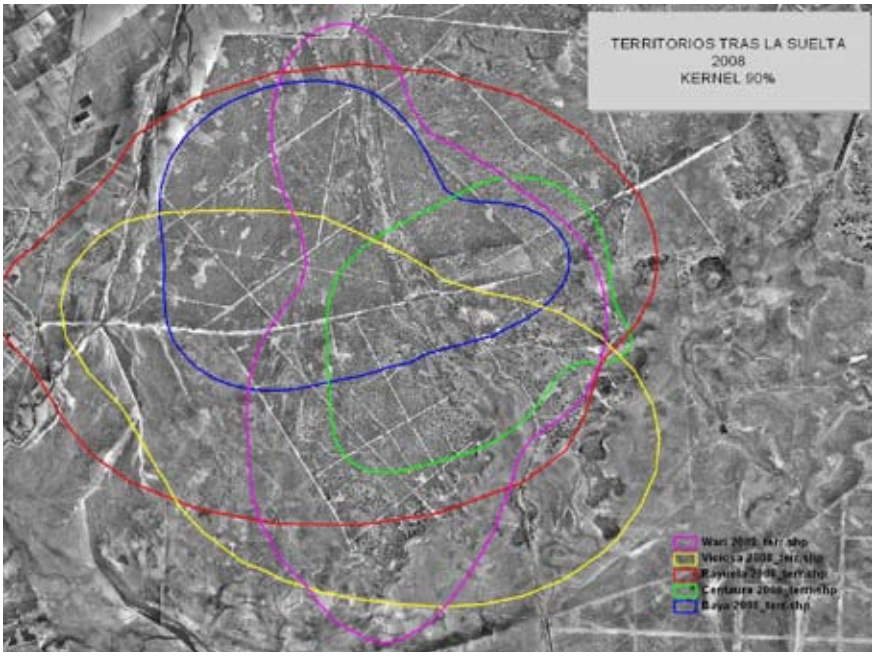

Figure 1 (b). Redistribution of territories six months after release.

Figura 1. (b). Redistribución de territorios seis meses después de la suelta.

Ha acclimatization pen. The chain link enclosure was 3.85 m high with an additional 0.5 m buried underground. Inside the enclosure there were Suplementary Feeding Stations (SFS) as well as a den site. Prior to *Baya*'s acclimatization to the release site, his own scats as well as scats from the three resident females were scattered in specific locations of the enclosure. Actual placement of the acclimatization pen was carefully chosen after evaluating the home-range overlap (using a 95% kernel) of the three territorial females (Figures 1a and b).

The final decision regarding the moment of actual release was determined taking the three following factors into account:

- Positive and continuous interactions (through the wire mesh) of *Baya* with the territorial females.
- Estimation of the timing of estrous of the three territorial females based on their birthing periods in previous years.

Figure 2. Moment of interaction between *Baya* and *Wari*, which marked the end of the acclimatization period.

Figura 2. Momento de interacción entre *Baya* y *Wari*, que marcó el final del periodo de aclimatación.

Figure 3. *Baya* (above) and *Rayuela* (sitting inside the Suplementary Feeding Station).

Figura 3. *Baya* (arriba) y *Rayuela* (sentada dentro del Cercado de Alimentación Suplementaria).

- Establishing a maximum limit for holding the male in the pen if no interactions with females had been observed. It was decided that Jaunaury 10th would be the maximum waiting period, always considering the observed behaviours during the acclimatization phase.

In order to detect the different behaviours, the acclimatization enclosure was equipped with a robotized (365° movement) infrared camera that was operated by project personnel 24 hours per day. One of the main objectives to be attained with this effort was to learn as much as possible from this release in order to improve techniques future reintroductions.

Baya was released on January 1st, 2008 (Figure 2). Project personnel estimated that the animal was properly acclimated to the site, considering that there have been a large number of positive interactions through the mesh with the three territorial females present in the area. The actual release took place after one of the females spent more than a day in the vicinity of the enclosure, vocalizing towards the male and showing signs of estrous.

Post-release monitoring

Intensive post-release monitoring efforts were conducted by the project's specialized staff in order to learn as much as possible from this release. These efforts continue to date but in a less intensive way.

Radiotelemetry

After release, at least two daily locations were obtained from *Baya*. The animal was followed for a while if it presented activity and, at the same time, all three territorial females were also located. After two months, and given that *Baya* had established himself in the area, he was included in the regular radio-monitoring protocol, with at least 2-3 locations per week.

Phototrapping and tracking

Suplementary Feeding Stations and the bounder of the enclosure are equipped with photo-trapping cameras, which have allowed for a precise control of the animals and their use of the enclosures (Figure 3). Altogether, a total of 212 lynx photographs have been obtained from the six photo-trapping stations during a 6-month period (January through June).

Monitoring gene flow

This genetic aspect of the project is monitored through two kinds of efforts: sampling of mixed-origin cubs for paternity tests (Godoy et al., this book), and identifying individual lynxes via scat collection. The latter method could become an effective and non-invasive way of studying gene flow throughout the Doñana population.

Conclusions

Six months after his release, we consider that *Baya* is effectively established in Coto del Rey, since he has never dispersed outside this nuclei. During the 2008 breeding season, *Baya* mated with the three adult females of this nuclei (Figure 1.B), although not with the 2-year-old subadult. Three of the eight mixed-origin cubs he has fostered have already reached dispersal age. We consider that this first stage of the re-stocking project, which involved ensuring the settlement of a Sierra Morena male in Doñana, has been successful. More time is needed to assess the genetic impact of this management action at the population level.

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Photo: E. Abad

Photo: Marianne Hartmann

If a cat does something, we call it instinct; if we do the same thing, for the same reason, we call it intelligence.

Will Cuppy

Breeding European wildcats *(Felis silvestris silvestris, Schreber 1777)* in species-specific enclosures for reintroduction in Germany

Cría del gato montés europeo *(Felis silvestris silvestris, Schreber 1777)* en recintos específicos para su reintroducción en Alemania

Marianne Hartmann-Furter

Resumen

Generalmente, se considera que el hábitat natural de una especie es aquel en el que se satisfacen mejor las necesidades del animal en cuestión. Por lo tanto, el comportamiento de los animales que viven en libertad se puede utilizar como base para el diseño de instalaciones en zoológicos. En un estudio experimental a largo plazo desarrollado en Suiza, se diseñó un recinto específico para el gato montés europeo, destinado a proporcionar a los animales todas las estructuras y estímulos importantes para la expresión de sus diversos comportamientos en función de todos sus ciclos funcionales. En dicho recinto los animales no desarrollaron ningun comportamiento anormal y mostraron un patrón de actividad similar a la de sus congéneres silvestres. Mediante un dispositivo electrónico para el suministro de alimento especialmente adaptado a las necesidades de la especie, los animales pudieron expresar prácticamente todo su rango de comportamientos naturales de caza. Las estructuras básicas se colocaron en el recinto siguiendo una disposición minuciosamente estudiada, y el comportamiento del cuidador se tuvo en cuenta como factor de igual importancia. Este recinto, que se ha adoptado en distintos zoológicos, ha servido de referencia en una serie de experimentos realizados para determinar los límites de adaptabilidad de la especie.

Desde 1993, las crías obtenidas de los ejemplares que viven en estos recintos se han destinado al proyecto de reintroducción del gato montés en Baviera (Alemania). Entre 1984 y 2008, un total de 580 ejemplares criados en cautividad fueron liberados en tres regiones distintas de Baviera. En 1999, se realizó el seguimiento de 11 ejemplares con radiotransmisor en un estudio piloto. Después de ser liberados de su jaula en el bosque, los gatos monteses deambularon entre tres y 20 días antes de establecerse en algún lugar. Tres individuos fueron atropellados al cruzar carreteras en las dos semanas posteriores a su liberación y otros dos no pudieron ser localizados. Todos los demás gatos monteses sobrevivieron, al menos tanto como las baterías de sus radio-collares y se probó que dos de ellos seguían vivos 11 meses después de su liberación. Además,

se obtuvieron pruebas sobre el terreno que indicaban que los gatos monteses no tuvieron problemas a la hora de conseguir suficientes presas en el medio silvestre. En este sentido, este trabajo muestra que los gatos monteses criados en cautividad que crecen en recintos específicos para la especie están bien adaptados para sobrevivir tras su liberación en el medio silvestre.

Palabras clave
Cría en cautividad, dispositivo para el suministro de alimento, comportamiento del cuidador, radio-seguimiento

Abstract
The natural habitat of a species is commonly regarded as the environment where the needs of the animals are best met. Therefore, the behaviour of animals living in the wild can be used as a basis for designing zoo environments. In the course of a long-term experimental study in Switzerland, a species-specific enclosure for European wildcats was developed in order to provide the animals with all the structures and stimuli relevant to their behaviours as they relate to all functional categories of behaviour. In this enclosure the wildcats were free from behavioural disturbances and showed an activity rhythm similar to the one of their wild conspecifics. An electronic feeding device, specifically tailored to meet the wildcats' needs, enabled them to express almost their entire range of natural hunting behaviours. The behavioural results showed that the essential structures must be placed in a particular arrangement within the enclosure, with the keeper's appropriate behaviour towards the animals as the second and equally important factor for the animals' welfare. This enclosure design, which has been adopted by several zoos and wildlife parks, served as a baseline for a series of experiments that were conducted to determine the limits of the species' adaptability.
Since 1993 the offspring of the cats living permanently in these enclosures have been provided to the wildcat reintroduction project in Bavaria, Germany. Between 1984 and 2008, 580 captive-bred wildcats were released in four different regions in Bavaria. In the course of a pilot study in 1999, we were able to radio-track 11 wildcats. After leaving their cages in the forest, the cats were wandering around between three and 20 days before they settled down. Three cats were killed crossing roads within the first two weeks after their release and two animals could not be tracked. All other cats survived at least as long as the batteries of their collars kept working and there was proof for two of them still being alive 11 months after their release. We have obtained evidence indicating that the cats had no problems with procuring enough prey in the wild. This work shows that wildcats raised in species-specific enclosures are well adapted for survival after being released into the wild.

Keywords
Captive breeding, feeding device, keeper behaviour, radio-tracking

Breeding European wildcats *(Felis silvestris silvestris, Schreber 1777)* in species-specific enclosures for reintroduction in Germany

Marianne Hartmann-Furter

Introduction

Wildcats are kept in many zoos and wildlife parks. In traditional enclosures wildcats are often invisible, because they are hiding all day long. However, field studies have shown that wildcats in their natural habitat are active during the day as well (Stahl, 1986; Liberek, 1999). On the other hand, when some of the wildcats in traditional enclosures are active, they often carry out pronounced pacing (Hartmann, 2000). Not only stereotypical walking, but apathetic resting is also an abnormal behaviour (Böer and Dittrich, 1982; Wiepkema, 1983). Both types of behavioural disturbances can indicate that the housing and caring system is inadequate to satisfy the behavioural needs of the animals and therefore reflects a poor welfare situation (Fraser, 2008; Hosey et al., 2009). Since the European wildcat is a species that is currently being reintroduced into areas where it became extinct, the quality of the housing systems for rearing release candidates may play a crucial part in their successful reintroduction.

The goal of this project was to develop a species-specific enclosure and housing system for the European wildcat, where animals would not develop any abnormal behaviours and would be able to perform the whole range of their natural behaviour patterns. The problem of inadequate enclosures is usually approached through environmental enrichment, which is a suitable method of improving the living conditions of wild animals in captivity (Young, 2003; Martos, this book; Manteca, this book). However, in some cases, this method may prove inefficient for reaching the goal of species-specific housing conditions. For instance, some of the animals living for an extended time under inadequate conditions develop serious behavioural anomalies, which, to some extent, are irreversible (the author's own observations). These animals may no longer be able to make use of an enriched environment nor to react to the respective stimuli in a species-typical way. In order to avoid these problems, I used a different approach by developing an adequate housing system right from the beginning.

Enclosure design and behavioural results

An enclosure was constructed where the cats were provided with a variety of structures and stimuli so that a wide choice existed for the animals in every functional category of behaviour (Figure 1). Sometimes the best approach to designing species-specific environments for captive animals is supposed to be that of imitating a section of the natural habitat to the greatest detail. However, if a small section of a wildcats' natural environment is cut out, not all the structures essential to the animals' behaviour may be found within this section. Therefore, an enclosure should not be an imitation of a section, but rather a distilled version of an entire wildcat home range with all elements needed to perform a wildcats' natural behaviours. The most important behaviour-releasing

Photo: Marianne Hartmann

Photo: Marianne Hartmann

Figure 1. The species-specific enclosure contains all the structures and stimuli essential for the wildcats' natural behaviour.

Figura 1. Las instalaciones específicas para gato montés contienen todas las estructuras y estímulos esenciales para que los gatos desarrollen comportamientos naturales.

Photo: Marianne Hartmann

Photo: Marianne Hartmann

Figure 2. (a) Just as free-living wildcats wait in front of a mousehole, so do the cats in the enclosure in front of the foodboxes and (b) catch food items as soon as they are released.

Figura 2. (a) Al igual que los gatos monteses esperan enfrente de la ratonera, los gatos criados en estas instalaciones esperan frente a las cajas de Madera y (b) cogen los alimentos conforme caen de la caja.

stimuli to be provided in a wildcat enclosure are those of the behavioural categories of resting, climbing and hunting. In the experimental enclosure I offered resting places of different qualities such as degree of exposure, shelter, view, etc., as well as climbing structures of different heights and spatial alignment, different diameters, and of various types of ramifications with or without cover. Hunting is the predominant activity of free-ranging wildcats (Stahl, 1986; Liberek, 1999). This behaviour is reduced to almost zero under housing conditions where the animals are fed every day at the same time and in the same place. Offering wildcats live prey is not sufficient to meet their behavioural needs, because only a fraction of their natural hunting behaviour is exhibited, mainly catching and killing (Hartmann, 2000). However, wildcats spend most of their hunting time waiting, listening, being alert and exploring (Stahl, 1986). In order to simulate the natural hunting situation of a wildcat in the wild, an electronic feeding device was developed (Hartmann, 2000), which provided the cats with the same stimuli and in a similar temporal and spatial regime as it is encountered by their wild conspecifics when hunting. Up to 20 boxes of different sizes for different food items were installed in various places within each of the 150 - 370 m^2 enclosures. Everyday some of the boxes were randomly chosen to be filled with dead mice, rats or chickens. The boxes were opened at random times by an electronic control, so that the cats never knew where or when a food item would appear: the same situation as with wildcats hunting in the wild (Figure 2). From some of the boxes, the food items were pulled out by an elastic cord, and the cats had to catch and pull the mouse or rat off the cord. The latter was accomplished by a bite analogous to the killing bite: the cat had to keep biting as long as it felt any resistance. As a result of this feeding regime, random in time and space, the cats showed a significantly higher level of overall alertness than cats fed in a traditional manner (Hartmann, 2000).

The wildcats living in the specifically designed enclosure and being fed by the electronic feeder did not develop any abnormal behaviours such as stereotypies or apathy (Hartmann, 2000). Furthermore, the animals in this enclosure showed activity patterns similar to those of their wild conspecifics (Stahl, 1986; Liberek, 1999). The reproduction rate of these animals was higher than the one known for cats living in traditional cages (Hartmann, 2001). Although breeding success per se cannot be used as a parameter for good housing conditions, it can

Photo: Marianne Hartmann

Photo: Marianne Hartmann

Figure 3. (a) Female leading her kittens on their first excursion through the enclosure; (b) After weaning, kittens spend a lot of time with their father.

Figura 3. (a) Hembra llevando a sus crías en su primera excursión por la instalación; (b) Tras el destete, las crías pasan mucho tiempo con su padre.

Photo: Marianne Hartmann

Photo: Marianne Hartmann

Figure 4. (a) Captive female in an unusual position after her enclosure had been entered by a careless keeper; (b) Three weeks after the keeper had stopped working at the cat station the same female stays relaxed on the ground.

Figura 4. (a) Hembra de cautividad en una posición poco usual tras la entrada de un cuidador poco cuidadoso en su instalación; (b) Tres semanas después de que el cuidador haya dejado de trabajar en el centro, la misma hembra se mantiene relajada en el suelo.

still be an indicator when compared with traditional housing systems and with the breeding success of animals living under natural conditions.

The wildcats in this enclosure showed a highly developed social behaviour. This was also due to the fact that breeding pairs were permanently kept together and sometimes with other family members as well (Hartmann, 2001) (Figure 3).The richly structured enclosure with the electronic feeder served as a baseline for a series of experiments that were conducted to test how far the complexity of this environment could be reduced without causing any changes in the cats' behaviour and without provoking any abnormal behaviours; and thus to determine the limits of the species' adaptability. The results of these experiments showed that in a species-specific wildcat enclosure, the relevant structures and stimuli not only had to be available, but also had to be placed in a particular arrangement.

The results of the behavioural observations also showed that there is a second and equally important factor for the animals' welfare, although this factor is very often neglected: this is the appropriate behaviour of the keeper (Hartmann, 2008). A good keeper makes the animals feel safe in their artificial environment, even in his or her presence. The experimental design of the project required that the animals continued the behaviours they were engaged in when someone entered the enclosure. Otherwise the behavioural data would have been biased by the reactions to the keeper, as it was observed that behavioural changes could persist for several hours after the keeper had left the enclosure. This was demonstrated when a specific keeper did not follow the guidelines issued to all keepers concerning their correct behaviour towards the cats. From the panic reactions shown by the cats it was assumed that this person did not talk to the animals and chased them away for cleaning their enclosures. Two juvenile females even developed stereotypical behaviour starting as soon as someone entered their enclosure (Hartmann, 2008). The stereotypies persisted for about two hours even after the person had left the enclosure. The two females were the first wildcats ever to develop stereotypies in the species-specific enclosures. Both had been particularly confident cats before and it is therefore possible that the keeper had tried to touch or even grasp them. Some cats thereafter made a habit of hiding early in the morning, before a keeper arrived, and of not reappearing until the late evening. The dramatic behavioural changes, displayed by

Figure 5. (a) Mouse-cage in the wildcat enclosure in Wiesenfelden for live prey feeding; (b) Enclosure at the release site in the Bavarian Spessart.

Figura 5. (a) Caja de ratones para alimentación con presa viva en las instalaciones de Wiesenfelden; (b) Instalaciones en el lugar de reintroducción en el Spessart de Baviera.

Photo: Marianne Hartmann

Photo: Marianne Hartmann

all of the cats living in the cat station at that time, disappeared only a few weeks after this keeper had stopped working at the cat station (Hartmann, 2008) (Figure 4).

Conclusions

The incident with one specific keeper showed that even in a well-designed species-specific enclosure the inadequate behaviour of a keeper may have a strong negative impact. From my behavioural observations I conclude that the following two factors are of equal importance for the welfare of European wildcats under captive conditions: a species-specific enclosure design as well as the keepers' appropriate behaviour towards the animals.

If planning to provide captive-bred animals for reintroduction programmes it has to be kept in mind that the keepers' behaviour may influence a successful release later on. European wildcats can be habituated to a single person, which means that the habituated cats do not generalize, but hide as soon as they perceive an unknown person (Hartmann, 1994). This feature possibly contributes to a successful release of captive-bred wildcats as well. With animal species that are more confident with humans in general than the European wildcat, the behaviour of their keepers and other humans in their captive environment has to be considered carefully in view of a possible impact on the animals' later survival in the wild.

Reintroduction

Introduction

The wildcat had probably become extinct in Bavaria (Germany) by the end of the 19th century (Büttner and Worel, 1990). In 1984, the Bund Naturschutz in Bayern started a project under the direction of Guenther Worel and Hubert Weinzierl to reintroduce this species. As a first step, educational campaigns were conducted for several years and an evaluation of the suitability of habitats was carried out (Worel, 2009). Between 1984 and 2008, 580 wildcats were released in four different Bavarian regions, namely the Spessart, the Steigerwald, the Hassberge and the Vorderer Bayerischer Wald.

Material and methods

In order to avoid endangering autochthonous populations by removing individuals for translocations, captive-bred cats were exclusively used for the reintroduction programme. Some of them were bred at the Bund Naturschutz wildcat station in Wiesenfelden, in enclosures offering naturalistic structures. Others were donated to the reintroduction project by more than 30 different zoos and wildlife parks in Europe. Since 1993 the offspring of the cats living in the Swiss Bockengut enclosures have been provided as well.

Cats coming from zoos were collected at the Wiesenfelden facilities where they received training for several months before being transported to the release sites. To a large extent these cats were trained by feeding them live prey. Mice and rats were released into a richly structured, escape-proof cage inside the wildcat enclosure, where they were able to hide (Figure 5a). Larger animals such as pigeons and rabbits were released directly into the cat enclosure. This method offers good opportunities for zoo-bred cats to be trained to catch and kill: in the

absence of people, also shy cats are given the opportunity to catch and kill prey. However, as the wildcats learn quickly about the practice by the keeper of putting mice into the mouse cage, which becomes the signal for them to start hunting, this method is not suitable for long-term use and cannot keep the cats busy with hunting for hours as it is the case in the wild (Hartmann, 2000). Only the cats originating from Tierstation Bockengut, Switzerland, were released without any further training, because they had been trained extensively in their rearing enclosures by means of the electronic feeder described above.

After having been transported to the reintroduction area, the cats were kept for several days in enclosures situated in the forest in order to let them recover from transportation (Figure 5b). Finally, the cage doors were opened to allow the cats to leave the enclosures in the absence of people. Some of the cats were released from specifically designed and arranged spots called "biotopes", to which they were transferred in their familiar sleeping boxes from the Wiesenfelden enclosures (Worel, 2009). At that point, they had the choice to leave anytime. In both release procedures food was provided as long as there were signs of wildcat presence at the release site. The feeding period thereby varied from one day to several weeks.

Post-release monitoring and results

Several questionnaire surveys as well as road-kill analyses showed that captive-bred wildcats managed to survive in the wild and established core populations from where animals dispersed into surrounding areas (Büttner, 1991; Eppstein, 1995; Knapp, 2002). Furthermore, there was proof of wildcat reproduction in the Spessart and in the Vorderer Bayerischer Wald (Büttner, 1991; Eppstein, 1995). However, apart from a radio-tracking study at the beginning of the reintroduction (Heinrich, 1992), no comprehensive monitoring studies have been carried out so far in order to measure the success of the reintroduction programme. Therefore, the number of wildcats currently living in Bavaria is unknown. Lately, the question arose as to whether self-sustaining populations already exist, so that releases could gradually be stopped, or whether further releases would be necessary in the respective reintroduction areas.

In 1999, we were able to conduct a pilot study in the reintroduction area of Spessart, Germany (Nabulon and Hartmann, 2001). Our main interest was focused on the behaviour and the survival of the released cats. Eleven wildcats were equipped with radio collars and were released from two sites in the Spessart in different seasons (Figure 6). Eight of these cats had been bred in the Bockengut enclosures in Switzerland, whereas three cats came from zoos. Five of the cats from Tierstation Bockengut were released in June. They were wandering around for three to 20 days before they settled down. One male travelled almost 100 km in three weeks. The principal movements of the cats were recorded at night. After their dispersal period had finished, all five cats remained in their respective home ranges and did not relocate at least as long as the batteries of their collars kept working. Two cats were seen and identified 11 months after their release. One of them was captured, in excellent shape, equipped with a new radio collar and released again.

Photo: T. Nabulon

Figure 6. Wildcat with radio collar.
Figura 6. Gato montés con radio-collar.

Six more cats were released at a different site within the Spessart in September. Three of them were killed while crossing roads within the first two weeks after their release. We assume that the high mortality rate in autumn was mainly due to seasonal effects. With dusk setting in earlier in autumn, movements of the cats were registered already in the earlier evening, coinciding with a time of heavy traffic. Therefore, the risk for a cat of being run over by a car was much higher in autumn than in summer, when the cats started to move at later hours. Our direct field observations as well as the stomach analyses of the animals killed by traffic showed that the cats were able to catch enough prey after their release. The behaviour of the released cats did not seem to differ from that of wildcats in autochthonous populations.

Conclusions

The results of this pilot study showed that the wildcats bred in the species-specific enclosures were able to survive in the wild without any further training. This means that the cats in these enclosures find all the structures and stimuli necessary to

perform their natural behaviours, to the extent that they are well adapted for surviving in the wild. Our conclusion is that the first three weeks after being released are critical for the cats' survival: they have to orient themselves, to get acquainted with their new environment and to catch enough prey while trying to find an unoccupied and suitable territory.

Whether zoo-bred cats trained with live prey at the Wiesenfelden Station have the same survival rate after release compared to cats bred in the species-specific enclosures still needs to be determined. After the pilot phase, a three-year study was planned, but it could not be implemented up to now. Following the IUCN Guidelines for Re-introductions (IUCN, 1998), data on the behaviour and survival of the released animals, on population density as well as on successful reproduction of the reintroduced population are to be collected for measuring the success of a reintroduction programme.

Captive-bred animals are not necessarily less suitable for reintroduction programmes than wild-caught and relocated individuals, provided that they receive proper training and are given the opportunity to acquire foraging skills and other essential abilities. Furthermore, rearing conditions should prevent animals from developing behavioural disturbances, which may disable them later on to react adequately in unfamiliar or critical situations. Removing individuals from autochthonous populations for relocation programmes might disturb local social systems, and thus impair the source population. Particularly, in the more solitary cat species, hardly any data are available yet on the effects of removing individuals from the breeding stock and on whether this would have an impact on the reproduction rate of the respective populations.

Acknowledgements

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Climb the mountains and get their good tidings. Nature's peace will flow into you as sunshine flows into trees. The winds will blow their own freshness into you... while cares will drop off like autumn leaves.

John Muir
(1838-1914)

Photo: Wildlife Conservation Society; (ISUNR camera trapping)

Breeding Far Eastern leopards for reintroduction: the zoo programme perspective

Cría del leopardo de Amur para su reintroducción: perspectiva del programa de cría en zoológicos

Sarah Christie

Resumen

El leopardo de Amur *(Panthera pardus orientalis)* es una de las dos especies de felinos de tamaño grande a mediano para cuya recuperación los expertos del Grupo de Especialista de Felinos de la IUCN considera necesaria la reintroducción de individuos procedentes de zoológicos. La otra especie para la que esto se considera necesario es el lince ibérico *(Lynx pardinus)*. Además de la planificación habitual destinada a atajar los problemas relacionados con la liberación de grandes predadores, es necesario establecer estrategias adecuadas de gestión de la cría y la liberación de la población de origen cautivo. En ambos ámbitos, los aspectos sociopolíticos suelen ser mucho más problemáticos que los biológicos. Este capítulo analiza los problemas biológicos y sociopolíticos asociados a la obtención de leopardos de Amur aptos para programas de reintroducción a partir de los individuos que se encuentran en distintos zoológicos del mundo. Además, se tratan algunos aspectos relevantes respecto a la selección de áreas de suelta, de estrategias de cría y liberación, así como al diseño de las instalaciones donde se mantiene a los animales. La estrategia de cría para la reintroducción se encuadra bajo el contexto del esfuerzo global por conseguir apoyo para la conservación del leopardo de Amur por parte de diversos zoológicos del mundo, aunque en este capítulo no se pretenden describir todos los factores implicados en el desarrollo del plan de reintroducción para esta especie, que actualmente no está finalizado ni oficialmente aprobado.

Palabras clave

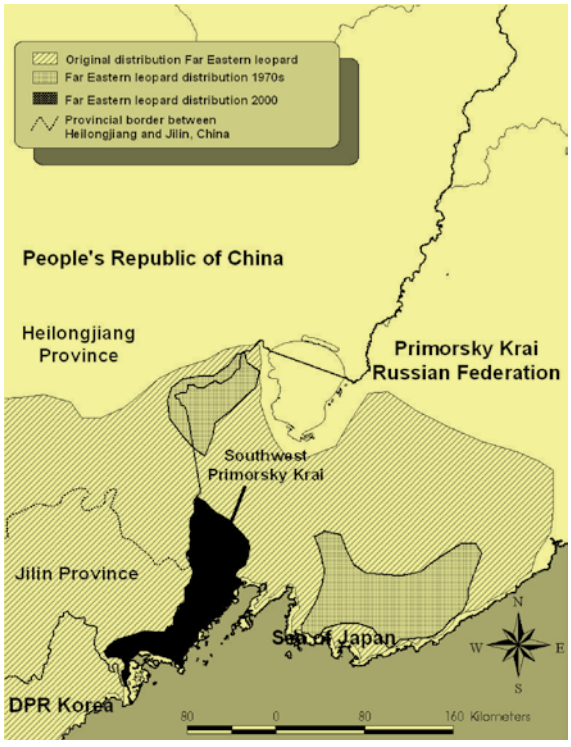
Leopardo de Amur, conservación, cría en cautividad, liberación, reintroducción

Abstract

The Amur leopard, *Panthera pardus orientalis*, is one of only two large/medium cats for which a reintroduction from zoo stocks is currently judged a necessary conservation action by experts, such as the IUCN/SSC Cat Specialist Group; the other one being the Iberian lynx, *Lynx pardinus*. In addition, to the customary planning to address the problems associated with the release of translocated large predators at a given location, it is also necessary to establish appropriate breeding and release-management strategies for the relevant zoo population. In both these arenas, the socio-political issues are far more problematic than the biological ones. This chapter examines the biological and socio-political problems associated with producing Amur leopards suitable for reintroduction from the stocks present in the world's zoos, and also considers some relevant aspects of site selection, breeding and release strategy, and enclosure design. It places the reintroduction breeding strategy within the context of overall generation of conservation support for Amur leopards from the world's zoos, but does not attempt to give an account of all factors involved in production of the Amur leopard reintroduction plan, which is currently neither complete nor officially approved.

Keywords

Amur leopard, conservation, captive breeding, release, reintroduction



Source/ Fuente: WCS/Tigris Foundation.

Photo: Wildlife Conservation Society; (ISUNR camera trapping)

Figure 1. Amur leopard current and historical range in SW Primorye, Russia.

Figura 1. Área de distribución actual e histórica del leopardo de Amur en el suroeste de Primorye, Rusia.

Breeding Far Eastern leopards for reintroduction: the zoo programme perspective

Sarah Christie

Introduction

The Amur or Far Eastern leopard, Panthera pardus orientalis, is arguably the world's most endangered big cat, with only 25–34 animals remaining in the wild (Pikunov et al., 2007) in southwest Primorye in the Russian Far East (Figure 1). The vast majority of its current range lies in Russia, although individuals do range over the border into neighbouring China and there are still sporadic, unverified reports from North Korea. The population has been recognized as a distinct subspecies (Miththapala et al., 1996; Uphyrkina et al., 2002) and deserves protection as a unique genetic contribution to the species and to the region. As a top-order predator, it is also a significant indicator of ecosystem health and integrity (Ray, 2005). Its current range lies in a region of importance to Russia's economic development and also of considerable biological significance in terms of both biodiversity richness and endemism; 31% of Russia's endangered species are found there and half of these are unique to the region. The area is bounded by China, North Korea and the Sea of Japan on three sides and by human-dominated areas of Russia on the fourth. Potential for expansion exists only over the border with China, and only if wildlife- and habitat-protection laws there are effectively enforced.

The extant population of Far Eastern leopards is at risk from a multitude of threats, including illegal killing of leopards and their prey, habitat loss due to fires and infrastructure development, disturbance and poacher access from road construction through leopard habitat, a decline in the effectiveness of protected area management in southwest Primorye and the potential ill effects of small population size such as inbreeding depression, disease or demographic imbalance. Genetic analyses (Uphyrkhina et al., 2002) indicate a loss of genetic diversity, but as yet there is no evidence of a consequent loss of fitness such as a decline in fertility or cub survival.

A range of conservation actions have been put in place by relevant non-governmental organizations working with the Russian authorities. The Amur Leopard and Tiger Alliance (ALTA, see www.amur-leopard.org) has a comprehensive, but under-resourced, programme to address poaching and habitat loss as a result of human-induced fires and wildlife–human conflicts, to monitor leopard numbers, to evaluate wildlife disease status in the region and to improve local understanding of, and attitudes towards, the leopards. The key implementing agencies in ALTA are the Wildlife Conservation Society (WCS) and the Phoenix Fund, with other partners involved in Russia to a lesser degree (Moscow Zoo, the Zoological Society of London [ZSL], the International Fund for Animal Welfare, the Tigris Foundation and Wildlife Vets International) or providing relevant funding (ZSL, the Tigris Foundation, AMUR, 21st Century Tiger, David Shepherd Wildlife Foundation, Wildlife Alliance and Helsinki and Minnesota zoos). The other key agency is the World Wide Fund for Nature (WWF Russia), which has an Amur leopard programme covering anti-poaching, public education and the establishment of necessary protected areas, and is a partner in WCS's ecological monitoring. ALTA and WWF Russia coordinate leopard-conservation activities on the ground and are also working together on reintroduction planning.

To safeguard against the potential loss of Far Eastern leopards in the wild, experts have concluded that it is highly desirable that a second wild population be established in the near future (WCS, 2001). This view is supported by the IUCN/SSC Cat Specialist Group. Achieving this second population would not reduce the need to protect the original population in southwest Primorye, but would provide an opportunity to increase the numbers and genetic representation of this subspecies and would also increase the probability of survival in the wild if one or some combination of the many threats in southwest Primorye should force that population to extinction.

A reintroduction plan for this leopard is currently being prepared by a group of Russian and international scientists and conservationists for submission to the Russian government, and discussion on the subject with government authorities in Moscow has begun, facilitated by WWF Russia. I stress at this point that nothing will happen on the ground until the necessary political support and substantial funding have been obtained. This chapter is not intended to outline the entire plan, as it is not yet completed let alone authorized. Instead, I discuss the biological and political factors associated with managing the zoo population to produce cats suitable for release and with related factors, such as selection of release site and design of the proposed breeding and release centre.

Source of stock for release

In general, it is widely considered preferable to use wild-caught, translocated individuals for reintroduction projects rather than captive-bred stock. For carnivores, Jule et al. (2008) have recently reviewed information on the difference in success rates, which confirms this statement. Factors affecting success include lack of experience in hunting, lack of experience in exploring and establishing a home range, lack of humanamoun other predator-avoidance behaviours and vulnerability to disease.

As Jule et al. (2008) note, it would be of interest to further analyse the effects of each of these factors. While some projects have provided captive-bred carnivores with experience with live prey, there have been few efforts to ensure that captive-bred individuals slated for release do not become accustomed to humans, a much more problematic characteristic than lack of hunting experience. Release programmes for social species may have the option of pairing a captive-born individual with a mate accustomed to life in the wild in order to facilitate the learning process, at least in circumstances where there are such animals available (i.e., supplementations of existing wild populations or ongoing reintroductions in which some animals have already become established). This would not be possible for the Amur leopard, which is not social and would be released into an area with no existing leopards, making the learning period prior to release at dispersal age even more important.

The wild population of Amur leopards, at about 35 individuals, is far too small to withstand removal of sufficient animals to establish a new population. It is also genetically depauperate in comparison to the zoo population (Uphyrkhina et al., 2002). Leopards for release would therefore be sourced from the managed conservation breeding programmes in the world's zoos, and pre-release breeding and management protocols are being designed to mitigate all the above factors as far as possible (see below).

The zoo population

The zoo population of this taxon is held almost exclusively in North America, Europe and Russia and has, since 1998, been managed to produce maximum conservation support for its wild conspecifics in terms of fund-raising, public awareness, generation of useful data and skills, and maintenance of a genetic "lifeboat" (see Christie, in press for a fuller account of the conservation support roles of zoo animals, which extend well beyond reintroduction). The European/Russian zoo breeding programme (EEP, European Endangered species Programme) for Amur leopards is coordinated jointly by myself at ZSL and Tanya Arzhanova at Moscow Zoo, and the North American/Canadian programme (PMP, Population Management Programme) is coordinated by Diana Weinhardt at Minnesota Zoo. ZSL has established a centralized service for EEP participant zoos and anyone else wishing to support the ALTA Amur leopard-Conservation Programme; a website at www.amur-leopard.org and a regular email service provide supporters with news, pictures and reports from anti-poaching, outreach, camera-trapping, fire-fighting and veterinary projects run by WCS, Phoenix, ZSL and the Tigris Foundation, and ZSL acts as a collection point for funds raised. The PMP has played a similar role, gathering funds from participants and forwarding them to ZSL. Overall, zoos have provided a significant proportion of the funds so far spent on the conservation of this leopard in the wild.

Numbers and genetics

In early 2008, there were ~130 leopards in the European Species Plan (EEP) and ~97 in the Population Management Plan (PMP). There are a few additional leopards in zoos in Japan, Korea and China, but these are inaccessible to the conservation breeding programme and/or of inappropriate genetic makeup to be useful. The EEP population currently retains 88.9% of wild-gene diversity, which is just below the generally accepted desirable level of 90% (see Leus and Lacy, this book). The PMP population contains no genetic lines that are not also present in the EEP population. Little can be done to improve gene diversity retention other than to breed from as many optimal pairings as possible on both sides of the Atlantic and, perhaps, if the necessary artificial reproductive techniques (ART) develop sufficiently and if the wild population proves to contain significant diversity not present in the captive stock, to use semen collected from wild male leopards to fertilize oocytes from the captive population.

To date, there have been very few instances of using ART to bring about genetically useful matings with real conservation implications from pairings that could not have mated naturally if given the chance, in felids or in any other group (see Wildt et al., this book). However, the Berlin Institute of Zoo Biology and Wildlife Research is now able to store feline sperm, ovarian tissue and early embryos produced by IVF and is researching application of these techniques to exotic cats with particular emphasis on the Amur leopard. If they are successful, their work could bring real conservation benefits. It could enable breeding from zoo cats that have died since their gametes were harvested and hence extend the life of the captive gene pool; it could transfer genetic material from the wild to the captive population without removing any leopards from the wild; and it could also enable careful planning of breeding for release. Embryos of appropriate genetic makeup and sexes could be stored and implanted as necessary into one or two females held in the *in situ* breeding centres, which would eliminate the need for long-distance transfers of pairs for breeding and would also ensure a balanced sex ratio in cubs produced for release, something that cannot be assured by any other means. However, these methods are both expensive and experimental; there is still a very long way to go in this arena, and current plans remain based on natural mating.

Breeding strategy in the Amur leopard EEP and the Founder 2 problem

As if this leopard did not already have sufficient difficulties, the managed zoo population in both the American and European regions includes a considerable contribution of genes from one founder –Founder 2– who was not an Amur leopard. (NB: Founder 89 has also been shown to have non-Amur leopard genes; however, his genetic contribution to the captive population is rather small in comparison and is not of sufficient significance to merit special attention in the genetic management strategy). Founder 2 is long dead, but molecular genetics on samples from his descendants (Uphyrkhina et al., 2002) indicates that he was probably of the geographically adjacent *japonensis* subspecies from northern China. If this is so, he was simply from the other end of what

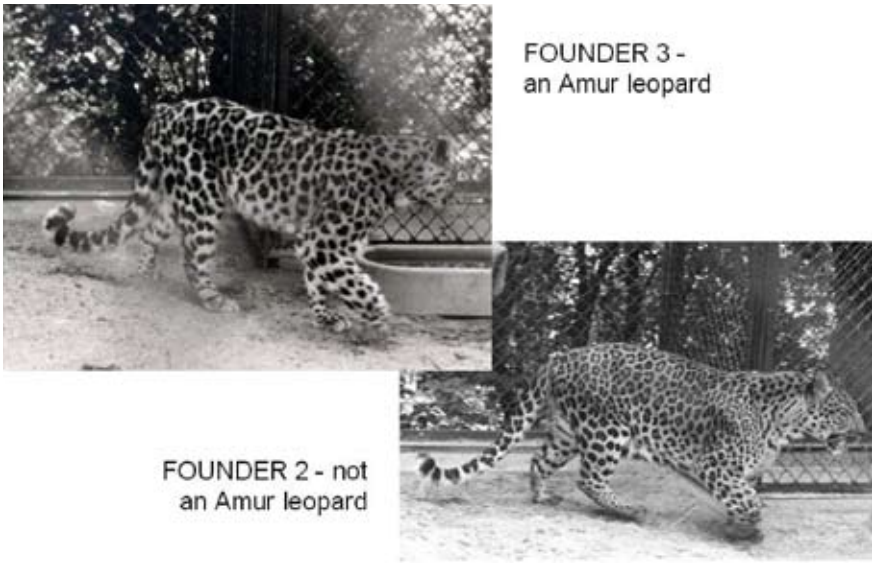


Figure 2. Founder 2 (not an Amur leopard) and his life-long mate Founder 3 (an Amur leopard) at Frankfurt Zoo in the 1970s). No copyright known.

Figura 2. Progenitores nº 2 (no leopardo de Amur) y nº 3 (leopardo de Amur), emparejados de por vida el uno con el otro en el Zoológico de Frankfurt en los años 70. Sin copyright conocido.

was quite recently a cline. Taxonomists favouring a morphological approach (who suggest his appearance is very different; see Figure 2) consider him more likely to be *pernigra* from the Himalayas. In the end though, this debate is purely academic. Taking a pragmatic approach, whatever his origin, his genes are so widespread within the zoo population, and the remaining wild population is so small and genetically impoverished that, as for the Prezwalski's horse population and its domestic horse genes (Bowling et al., 2003), there is no realistic option other than to retain his genes in the zoo and reintroduced population.

The debate over Founder 2 might be thought relatively inconsequential in biological terms, especially given the documented success in improving Florida panther, *Puma concolor*, viability using Texas puma genes (Pimm et al., 2006). However, relevant events clearly demonstrate that socio-political factors can often override biological ones in decision-making processes (Jiménez et al., this book). Initially, in the mid-1990s, representatives of European and Russian zoos were strongly opposed to retaining representation of Founder 2, largely on philosophical grounds, and strenuous efforts were made to breed the few available pure-bred leopards exclusively to each other. These pure-bred cats had all come from Pyongyang zoo in North Korea during the 1980s and 1990s, and were variously reported as wild caught or captive bred without any substantiating material. Genetic investigations by Uphyrkhina et al., (2002) concluded that they were closely related to the wild population in Russia and were also sufficiently related to one another to be the result of three generations of brother–sister pairings (Uphyrkhina, personal communication). Breeding attempts within this group largely failed to produce healthy offspring and for the past five years these cats, which where still alive and in breeding condition, have instead been paired with leopards containing low levels of Founder 2.

It was clear in 1998, and was further underlined at a meeting in Vladivostok, "Workshop on Conservation of the Far Eastern Leopard 2001" (WCS, 2001) –despite arguments that evolution might be expected to act on any undesirable genes present– that leopards with high levels of Founder 2 genes would not be acceptable to many scientists and conservationists for release. Hence, rather than simply treating Founder 2 as another founder on the grounds of his probable nearby geographical origin (according to molecular genetics), as the PMP has done, EEP strategy has been to manage breeding so as to minimize his contribution as far as possible while still maintaining acceptable overall levels of genetic diversity. The usual method of selecting cats for breeding on the basis of their mean kinship ranking (simply put, the level of unrelatedness to the rest of the population) has been balanced with consideration of their Founder 2 content, so that a cat with a high mean kinship rank but with more than 25% Founder 2 content might not get a breeding position while one with a lower mean kinship rank but only 12.5% Founder 2 is certain to do so. All leopards with more than 41% Founder 2 (simply a

convenient cut-off point in the distribution of percentages) have been excluded from breeding since 1999 and, in recent years, those with more than 30% have also been mostly excluded as numbers of animals with lower levels have risen.

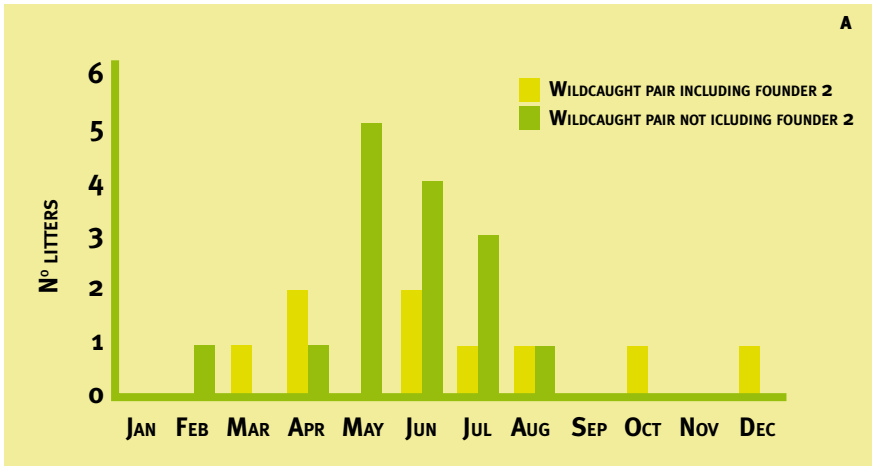
This policy has resulted in an overall decrease in the prevalence of Founder 2 genes and an increase in the number of leopards with low percentages of them. It is unfortunate that it was not possible to adopt this approach earlier, as several pure-bred leopards died without surviving offspring before the new policy was agreed. As of early 2008, 20% of the total EEP population (13 male and 13 female leopards) contained a Founder 2 contribution of 20% or less, as did 4% (two male and two female leopards) of the PMP population. Breeding from animals of between 20% and 30% Founder 2 will continue to some extent in order to conserve a wide gene pool in the population overall, but it is the pool of young leopards carrying a Founder 2 contribution of less than 20% that would provide the necessary breeding pairs for production of cubs for release in the Russian Far East.

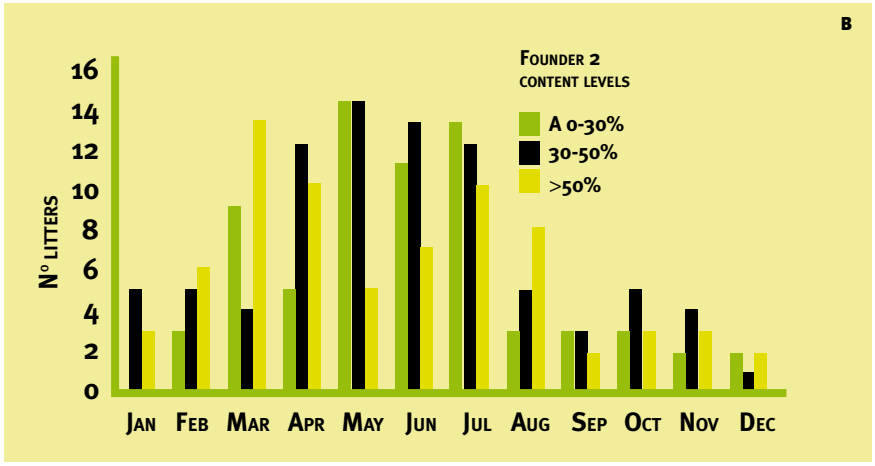
The PMP programme has recently recognized the political realities of breeding for possible reintroduction –i.e., that whatever the real biological consequences may be, many relevant scientists remain fundamentally opposed to Founder 2's inclusion– and has adopted the EEP approach of minimizing his contribution. Two young leopards with low Founder 2 content are being identified for shipment from Europe to Minnesota to assist in reducing overall Founder 2 levels in the PMP.

Melanism is present in the population, thanks partly to the enthusiasm with which its initial appearance was greeted by some participating zoos, which actively sought out and bred from these cats to the extent of importing them to Canada from Europe for the purpose. There are no records of the melanism gene in the wild population of Amur leopards, but it is not possible to attribute the gene in the zoo population exclusively to Founder 2 because all leopards with a genetic contribution from him also contain genes from his life-long mate, Founder 3. While the melanism gene could conceivably –given the snowy winters in the region– exert an impact on survival in the wild, being a recessive gene it would be likely to be expressed in only one cub per litter at most and to be rapidly selected against in the wild if it did increase mortality rates. The fact is, however, that when expressed it is visible and so, like the fox colour gene in the Prezwalski horse, is likely to attract intense hostility from those who are philosophically opposed to the inclusion of Founder 2 genes in the first place. Once again, socio-political factors outweighed biological ones in the management decision process and melanistic cats are now excluded from the breeding pool, although not all possible melanism gene *carriers* are excluded, as to do that would effectively cripple the Programme. Invisible genes (e.g., those affecting physiological processes such as temperature control) might have a more significant impact on survival in the wild. As we cannot detect them, however, the only possible strategy to mitigate their possible effects is to minimize Founder 2's overall contributions.

The matter of birth seasonality is an interesting one in this context. This is a factor that could compromise survival and could be affected by genes from another geographical location. It is also one which we can detect in zoo leopards. There are few data on birth seasonality from Amur leopards, but Amur tigers *(Panthera tigris altaica)* in the wild do not show a pronounced peak in birthing during the spring, in fact, most births are in late summer or autumn, with births reported in nearly every month of the year (Kerley et al., 2003). This could be considered surprising given the severe winters in the region. Captive Amur tigers, with a dataset of well over 4 000 births, do show a significant birth peak in April–June, with 45% of births occurring in those months (Traylor-Holzer, 2003), though births do occur throughout the year. Additionally, in two pure-bred Amur leopards in Prague Zoo, the quality of semen collected varied with season, with better-quality ejaculate obtained in spring and early summer than in December (Katarina Jewgenow, personal communication).

With this in mind, along with the need to allay as far as possible the fears of those objecting to Founder 2's genes, birth seasonality in the Amur leopard EEP with and without Founder 2 was investigated in 2001. Figure 3a shows the distribution of litters born to wild-caught pairs with and without Founder 2; there is a 2-month difference in average birth date between the two groups. Figure 3b compares birth distribution in leopards with low, medium and high Founder 2 content; the difference between the low and medium Founder 2 groups is statistically significant ($p>0.025$; $x^2 2 >20.12$, $df=11$, $p <0.05$ for each), indicating that Founder 2's genes do affect the birth season in this population.





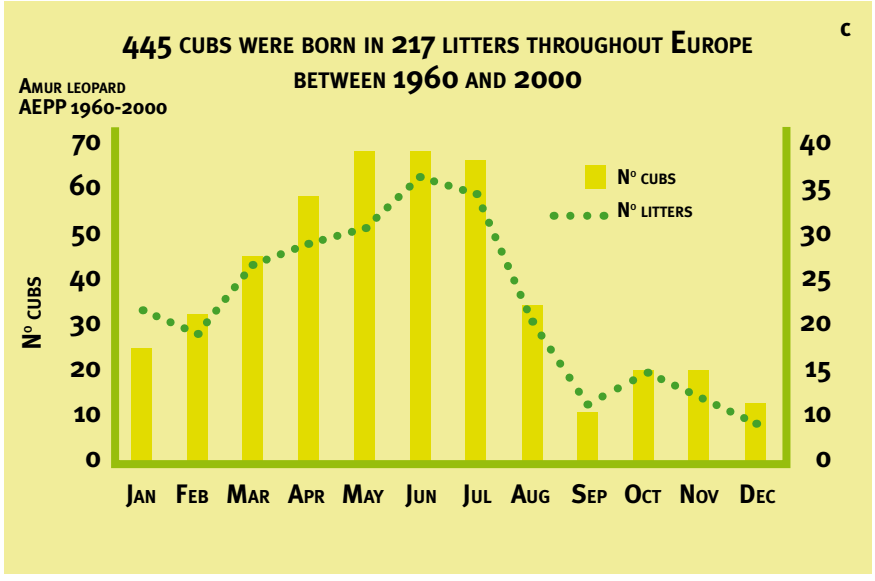


FIGURE 3. (A) BIRTH SEASONALITY IN PAIRS OF WILD-CAUGHT AMUR LEOPARDS NOT INCLUDING FOUNDER 2, CONTRASTED WITH BIRTHS TO FOUNDER 2 AND HIS LIFE-LONG MATE FOUNDER 3. (B) BIRTH SEASONALITY IN LEOPARDS WITH LOW, MEDIUM AND HIGH FOUNDER 2 CONTENT. (C) BIRTH SEASONALITY IN THE WHOLE POPULATION BETWEEN 1960 AND 2000. SOURCE: ZSL.

FIGURA 3. (A) ESTACIONALIDAD DE NACIMIENTOS EN PAREJAS DE LEOPARDOS DE AMUR CAPTURADOS EN EL MEDIO SILVESTRE, SIN INCLUIR AL PROGENITOR Nº 2, COMPARADAS CON LOS NACIMIENTOS DEL PROGENITOR Nº 2 Y SU PAREJA DE POR VIDA, EL PROGENITOR Nº 3. (B) ESTACIONALIDAD DE NACIMIENTOS EN LEOPARDOS CON BAJO, MEDIO Y ALTO CONTENIDO DEL PROGENITOR Nº 2. (C) ESTACIONALIDAD DE NACIMIENTOS EN TODA LA POBLACIÓN ENTRE 1960 Y 2000. FUENTE: ZSL.

However, the subsequent analysis of the whole population's birth distribution shown in Figure 3c clearly indicates that, overall, there is a peak in spring. As field scientists currently do not believe that this leopard is a seasonal breeder in the wild, they will presumably be less concerned about this factor in leopards for release than about melanism; but in any case, it seems that provided Founder 2 levels remain below 20%, there is unlikely to be an effect on birth seasonality. Some genetic lines in the zoo population have experienced high levels of inbreeding in the past, although management strategy over the past 10 years has ensured that current inbreeding coefficients are below 0.1. Past problems have been due partly to a shortage of founders, but also to a lack of active management prior to the mid-1990s, particularly in the pure-bred (and inbred) lines originating in Pyongyang zoo. At present, the EEP is collecting and collating data on any possibly inheritable defects, which have included deformed leg bones, cryptorchidism and "manx" tails, and ensuring that any affected animals are not included in the breeding pool. The bulk of the population is free from such problems. A veterinary team has been assembled by the EEP's veterinary advisor, John Lewis, to investigate specific factors where necessary, and a protocol for data collection has been circulated to participating zoos.

It is worth noting that in one instance of a possibly inherited defect –cryptorchidism– in a pure-bred cat, the strength of feeling among EEP participants about purity was such that attempts to breed from the animal in question continued despite clear veterinary advice pointing out that the problem is often associated with other damaging genes. As this leopard has also failed to show normal mating behaviour, ART has been used as well as natural mating attempts. However, no pregnancy has yet resulted.

Preparations in the field

Release-site selection

There is general consensus among stakeholders that the first effort should focus on establishing a second population rather than on supplementing the existing wild one given the potential veterinary, behavioural and genetic risks of adding captive-bred cats to the wild population and the lack of any evidence of loss of fitness resulting from small population size in the wild as yet. The release site for this second population should have the following characteristics:

- Be within the historical range of the Amur leopard (Figure 1).
- Be sufficiently separated from the current range to ensure no possibility of genetic mixing with the existing population.
- Be as far away as possible from human habitation in order to minimize chances of conflicts.
- Contain a high prey base of appropriate species.
- Contain cliffs and rocky areas to facilitate the leopard's use of refuges on release.
- Contain adequate infrastructure (roads, electricity and water supply) for management and monitoring activities.
- Be within a well-managed area with sufficient protection.

Additional criteria, including those related to the attitudes and reactions of local residents and other stakeholder groups, do of course need to be met before a reintroduction can proceed (see IUCN, 1998); here we are considering only criteria relating to site selection.

Lazovsky Zapovednik (zapovedniks are IUCN Category 1 protected areas) is located within the historical range and at the same latitude as the existing population (see Figure 4). Its physical characteristics also resemble the current range in that it is situated on the coast, which tends to create slightly warmer weather conditions, it contains similar cliffs and rocky areas, and the habitat types are also similar. Sika deer *(Cervus nippon)* occur at the relatively high density of 8.6 head/km^2, but species within the leopard's preferred prey-weight range (Hayward et al., 2007b) are less abundant (Alexander Myslenkov, personal communication). This is due partly to effective protection work carried out by the reserve staff with support from Phoenix Fund, but also to the fact that at the time the leopard became extinct in south Sikhote Alin, sika deer could legally be hunted there, while they are now fully protected. In the leopard's current range, it remains possible to legally hunt sika deer.

Tigers would present a risk to a small, reintroduced founder population of Amur leopards, in that intraguild predation (Palomares and Caro, 1999) has been demonstrated in the region (Aramiliev, personal communication).

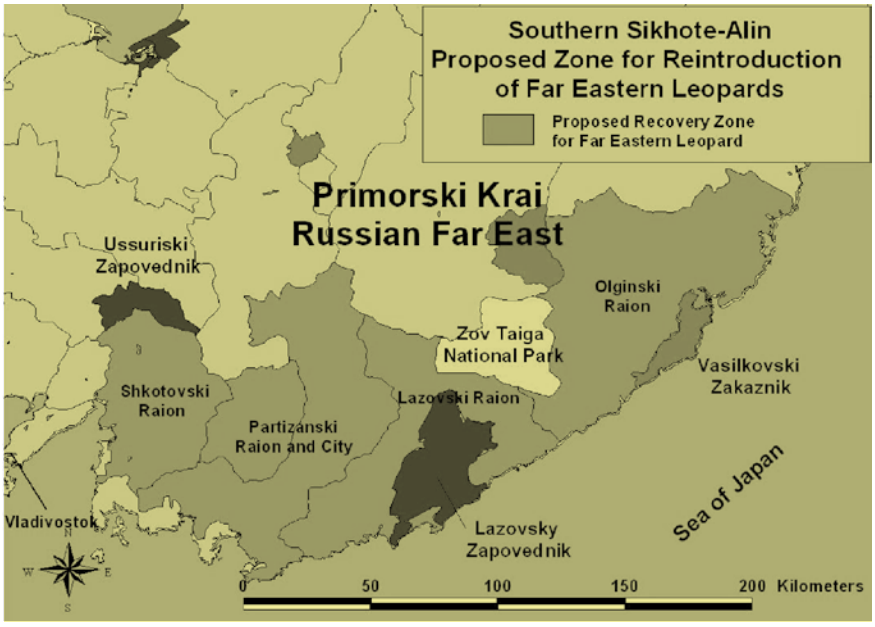


Figure 4. SW Primorye showing current leopard range and protected areas including Lazovsky Zapovednik.

Figura 4. Suroeste de Primorye, indicando el área de distribución actual del leopardo y las áreas protegidas, incluyendo Lazovsky Zapovednik.

Lazovsky contains tigers, as do all other potential release sites. Their presence is unavoidable and all that can be done is to take mitigating action, e.g. providing leopards for release with aversion training in relation to tigers and/or ensuring that site topography favours separation between the two as far as is possible. Spatial separation appears to exist in southwest Primorye, where tigers and leopards currently co-exist (Miquelle and Murzin, unpublished data), and is the basis for including "cliffs and rocky areas" which are assumed to provide refuge for leopards. Red deer, which are generally a preferred prey item for tigers but are too large for leopards, are present in Lazovsky but at low density (0.4 head/km^2, Alexander Myslenkov, personal communication), so the sika deer population there may be targeted by both tigers and leopards. As red deer are almost unknown in southwest Primorye, clearly it is possible for the two big cats to co-exist with sika deer as the primary prey item. Leopards take more small prey such as badgers and raccoon dogs than do tigers, so prey selection will not overlap completely.

Other factors

Other significant factors that must be addressed early in the planning process include: disease status of wildlife in general in the release area and of zoo leopards that may be used for breeding stock, local and political support for such a plan, and potential funding sources.

Acceptance of a reintroduction programme by local communities will clearly be critical to success, and social research to assess attitudes of local people is in the pipeline. While Phoenix Fund and ZSL staff have carried out studies in existing leopard range and Phoenix and WWF Russia have had considerable success in influencing attitudes towards tigers and leopards among children in southwest Primorye, work in the proposed release area is yet to begin, and Durham University is seeking funding for a 3-year study designed to assess local attitudes as a first step.

Steps must be taken to ensure that released cats do not harbour pathogens likely to adversely affect wildlife in the area and that they are not themselves vulnerable to pathogens already present in the environment. Towards this end, since 2006 ZSL and the Primorskii State Agricultural Academy, in partnership with WCS, have been implementing a 3-year programme focused on increasing wildlife health-monitoring capacity in the region, as well as collecting baseline data on wildlife diseases in the area and disease status in zoo leopards genetically suitable for production of cubs for release. Wildlife vets and students in the region participate in workshops that include lectures and hands-on training sessions, taught by international experts, with training programmes held in a local rehabilitation centre (Utyos) in Khabarovski Krai and in Moscow and Novosibirsk zoos. Training

sessions in the zoos have served the additional function of collecting samples from Amur leopards for disease analysis, as these are the only two zoos in Russia holding cats genetically suitable for reintroduction.

Other suitable stock in European and American zoos is also being sampled as part of the disease testing programme, with additional specialist investigations such as MHC testing and expert analysis of heart murmurs being coordinated by John Lewis. Meanwhile, samples are being collected in and around the proposed release area from tigers, wild ungulates, small carnivores, and domestic ungulates and carnivores. In Ussurisk, a laboratory belonging to the Academy is being renovated and outfitted to enable in-country sample analysis in the long term, although samples are at present being analysed in UK and European laboratories as well.

The draft reintroduction plan has so far been the subject of one governmental meeting in Moscow, facilitated by WWF Russia, and comments made have influenced subsequent work. When the plan is complete and officially approved, it will then be possible to approach potential funding sources. However, finding sufficient support for such a major effort represents one of the great challenges of the reintroduction effort.

Breeding and release strategy

If this reintroduction is to succeed, it is clear that the design of the breeding and release centre, and the management of the leopards within it, must focus strongly on overcoming the difficulties imposed by the captive origin of the cats. In addition, a "soft" rather than "hard" release strategy should be used (i.e. the breeding enclosure should be located at the point of release). Three necessary behaviours should, if possible, be acquired prior to release: hunting and killing of live natural prey, avoidance of humans and avoidance of tigers. (The leopards will of course also need to learn exploratory behaviour within the home range, but this is not a factor that can be addressed in the breeding enclosure other than by placing it within the release habitat).

This section of the reintroduction plan is not yet complete, and there appear to be no models. While various projects have experimented with hard- and soft-release sites and with varying levels of experience of hunting for zoo-bred cats before release, there appear to have been no serious efforts to date to avoid contact with humans and instil human-avoidance behaviours, let alone avoidance of larger predators, in such cats. Avoiding contact with humans involves a complete reversal of accepted zoo enclosure-design principles which, as well as ensuring a good viewing experience for the public, tend to focus strongly on ensuring that the animals can be observed, moved around, given treatments and captured by staff with maximum ease for the keepers and with minimum stress for the animals.

The outline presented here is therefore experimental, is still under discussion, and is in no way intended to provide a final or complete account of intended protocols.

Breeding-centre design

The breeding centre will need to include a short-term holding facility, a veterinary examination room, storage for equipment and supplies, and staff housing, offices and meeting facilities, as well as several breeding enclosures. The breeding enclosures would be located at a considerable distance from the rest of the centre to ensure that the animals in the enclosures could not smell, see or hear the humans present there. This stands in stark contrast to the reintroduction of African top-order predators that are intended for ecotourism purposes. Feeding live prey to the release candidates from birth is a highly desirable tactic and, if this strategy is to be used, thought will also need to be given to provision of breeding facilities for prey items, e.g. deer and rabbits. This approach, although likely to attract criticism from animal-welfare agencies, would have the significant benefit of ensuring that released animals are able to identify and kill appropriate prey species. Nonetheless, relevant Ethics Committees would need to carefully consider the costs and benefits. Provision of a couple of "leopard display enclosures" –located at the main part of the centre, well out of sight, sound and smell of the breeding enclosures might also be desirable, as the project would be bound to attract interest, and good public relations will be of paramount importance, yet people must be kept away from leopards intended for release. One of the display enclosures might perhaps contain a tiger, and it is conceivable that a tiger housed there could be useful in aversion training for release stock.

The centre, and particularly the breeding enclosure(s), would be located within the release site to allow a "soft" rather than "hard" release. Pairs of physically and behaviourally healthy zoo leopards of suitable genetic

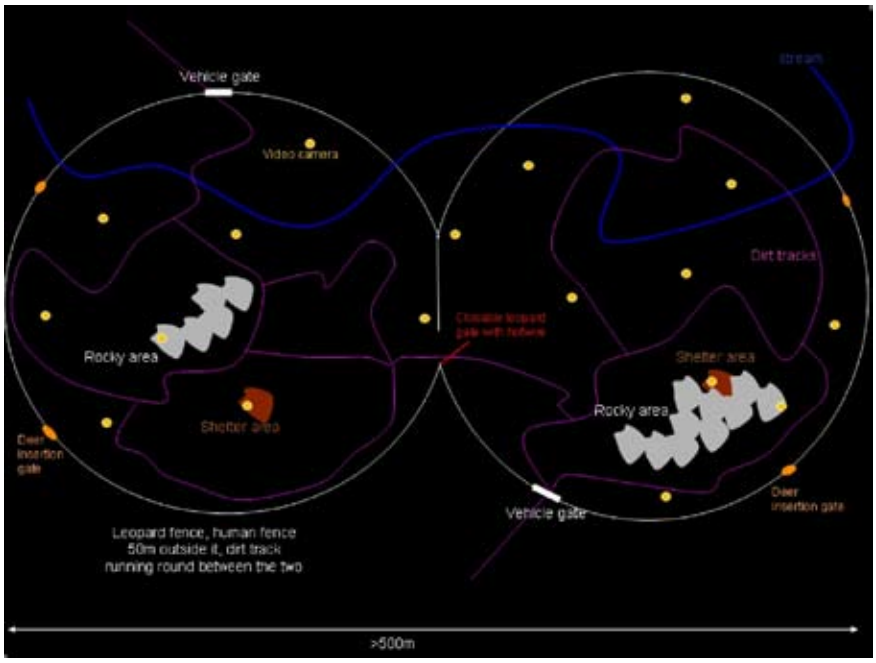


Figure 5. Amur leopard breeding and release enclosure design outline (not to scale).

Figura 5. Esquema del diseño de las instalaciones de cría y liberación del leopardo de Amur (no está a escala).

makeup, which had proven themselves to be successful breeders and rearers of cubs in zoo conditions, would be transferred to the facility for breeding purposes and returned to their home zoos when sufficient offspring from their genetic line had become established in the wild. Cubs would be born and reared with as little interference from humans as possible, with routine monitoring done long-range by video. The male would be removed as soon as pregnancy was confirmed. When the cubs were old enough to begin to learn to hunt, live prey would be supplied in the enclosure; basic hunting behaviour is instinctive in cats, and it is assumed that if cubs were given the opportunity to learn from experience while young, they would develop sufficient hunting skills to form a basis for a life in the wild.

When the cubs reached dispersal age, the mother would be removed, the cubs given a veterinary check-up and fitted with adult-sized radio collars, and the gates opened so that they could move out into the surrounding forest but still return to a known area for shelter and, if necessary, supplementary feeding.

More than one breeding and release enclosure should be established within reach of the centre, and consideration should be given to setting up one or more additional enclosures at a different location within the overall release area. Given that releases will need to be continued over a period of years, if leopards settle into home ranges near the release point there could be potential for aggressive encounters if further animals –particularly of the same sex– were released at the same site. The other components of the centre need not be duplicated to achieve this, but the holding facility at the centre should be designed to hold sufficient adult leopards to serve several breeding enclosures.

Design of breeding enclosures

It is imperative that leopards destined for release grow up without familiarity with humans and learn to fear humans as much as possible. The leopard breeding enclosure(s) associated with the centre should therefore be situated within reach of transport, water supply and electrical power, but out of sight, sound and smell of the other buildings necessary for the operation of the centre and of all associated human activities.

Breeding enclosures should be as large as can be achieved with available funds and should be in a wooded area so that the leopards have plenty of cover; they should not be visible to a casual observer unless at the edges

of the enclosure. Enclosures should take advantage of natural features in the landscape and, if at all possible, should include rocky areas, a natural stream for water, and natural shelter areas such as caves, overhangs or fallen/hollow trees. If natural shelter is not available in the area, it will need to be constructed from natural materials, i.e. trees and rocks. As few man-made items as possible should be present, and capture of leopards for radio collaring or final medical assessments would be performed by darting from vehicles, not by the normal zoo methods of simply shutting the animal into its night den for darting or accustoming it to sleeping in the intended transport crate. Monitoring of the cats would be carried out via video cameras scattered around the enclosures and linked to viewing screens in the staff areas.

Enclosures could be shaped in a rough figure of eight with the central connection containing a leopard-proof closable gate (Figure 5). This design would allow the leopards to be separated if necessary, or to be shut into one end to facilitate catching them or while live prey, if used, is released in the other end. The figure-of-eight shape would also allow for live prey to be chased around without being cornered, which would help the leopards improve hunting skills. Chasing deer along the fences would be to some extent inevitable, but it is at least possible to avoid corners. Leopards can climb, and their enclosures in zoos have traditionally been roofed, although larger modern facilities have departed from this model. Serious escape attempts are unlikely in a large densely wooded enclosure with plenty of food, but nevertheless the fence would need to be high, perhaps 5 m, with a substantial overhang. Use of hotwire is also desirable both to discourage escape and in the hope of conditioning leopards against approaching man-made structures. Although a wild-caught African leopard is known to have scaled a 3-m high electric fence in order to escape from a boma (Hayward et al., 2007a), that animal had a far stronger motivation for crossing the fence than leopards in these enclosures would have. Large gates into each half, and dirt roads within, would permit vehicle access for captures of leopards and release of live deer, if used.

Management of leopards

Leopards selected for breeding would undergo a final set of health tests before shipment from their home zoos, and would arrive in spring to allow plenty of time for acclimatization before the onset of winter. They would initially go into the holding facility for a quarantine and acclimatization period before transfer to the breeding enclosure.

All cats in the enclosure would be radio-collared at all times, to assist in locating them within the enclosure and with recapture should there be an escape. Expandable collars allowing for growth are available for young cats. Live prey, if used, would be introduced into the enclosure regularly via vehicles or through specially constructed gates, with the leopards shut into the opposite part of the enclosure each time to keep them as unaware as possible of the association between humans and food supply.

Monitoring via video cameras would help to establish that the female was pregnant and, once this was achieved, the male would be removed to the holding facility or perhaps a display enclosure. The cubs would be captured, collared and given a veterinary check-up as soon as they began to show independence from their mother. The mother would be removed at some point prior to the cubs reaching dispersal age, at which time they would again be captured, fitted with an adult-sized radio collar and given a final health check. All gates would then be opened and perhaps also the fence breached in a few places, the supply of live food stopped and, if necessary, bait used to tempt the young leopards out. The cats would be monitored as they dispersed, but supplemental food would still be provided, probably for several months.

Breeding leopards would be held in the centre until they had contributed sufficient cubs and would then be returned to their home zoo and replaced by other cats of different genetic lines. It is expected that the process of establishing a stable population would take at least 10 years.

Next steps

It is intended that the plan will be completed and submitted to the Russian authorities during 2008, after which final discussions on the work will take place and the plan will be amended accordingly. Health evaluations of zoo leopards will also continue during this period and should be completed in 2009. As and when official endorsement is forthcoming, it will be possible to seek funding, which will be the next big hurdle for the project.

In the meantime, all involved will continue their efforts to protect the existing wild leopards, and the European and American conservation breeding programmes in zoos will continue to be managed so as to

produce the maximum possible conservation support for their wild relations, as well as experienced young breeding pairs suitable for *in situ* breeding for release.

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Photo: Wildlife Conservation Society; (JSUNR camera trapping)

Wilderness is not a luxury but a necessity of the human spirit.

Edward Abbey
(1917-1989)

Photo: Mike Lockhart

Reintroduction of the Black-footed ferret to the great plains of North America: *Do we really have the capabilities, resources and socio/political will to recover critically endangered species in the United States?* An opinion

Reintroducción del turón de patas negras en las grandes llanuras de Norteamérica: *¿realmente disponemos de las capacidades, recursos y voluntad sociopolítica para recuperar las especies en grave peligro de extinción en los Estados Unidos?* Una opinión

Mike Lockhart

Resumen

Aunque en algún momento se pensó que era una especie extinguida, en 1981, se descubrió una población pequeña de turones de patas negras (*Mustela nigripes*; turón) cerca de Meeteetse, en el oeste de Wyoming (Estados Unidos). En 1987, sólo quedaban 18 ejemplares que fueron llevados a cautividad con el fin de evitar su extinción mediante un programa de cría en cautividad. El turón depende de tres especies de perritos de la pradera *(Cynomys* spp.*)* para su supervivencia; utiliza los perritos de la pradera como presa y aprovecha las madrigueras de éstos para sus refugios y guaridas. Las causas de que los turones estuvieran al borde de la extinción fueron la conversión de los pastizales naturales del altiplano en tierras de cultivo y las décadas de envenenamiento intensivo de los perritos de la pradera durante la primera mitad del siglo XX. Desde 1987 hay un programa internacional para la recuperación del turón que ha superado grandes retos y ha tenido un éxito notable. Entre los años 1987 y 2007, se criaron aproximadamente 6000 turones en cautividad y fueron reintroducidos más de 2400 en 17 espacios de distintos proyectos en el oeste de los Estados Unidos y México. No obstante, la reintroducción ha tenido distintos grados de éxito y algunos proyectos se vieron afectados por el impacto sobre las presas o el hábitat de una enfermedad introducida (la peste bubónica), la sequía y la política (con los correspondientes fracasos en la

gestión del suelo). La estima más reciente de la población indica que las poblaciones de turones silvestres representan sólo un 20% del objetivo original que se estimó para lograr que su clasificación bajara a un nivel de protección menor (mejoras en la conservación de la especie que modificarían su clasificación, pasando de estar "en peligro crítico" a "amenazada"). A pesar de que la Ley sobre Especies Amenazadas y otras leyes estadounidenses sobre el medio ambiente contemplan mandatos y directrices para la recuperación de especies en peligro de extinción y para la gestión correspondiente de suelo público de propiedad federal, posiblemente el mayor obstáculo para los avances recientes en la recuperación del turón haya sido la intervención política y el abandono de las leyes y políticas medioambientales (comportamiento mostrado por la Administración de los Estados Unidos entre 2000 y 2008). Tenemos la experiencia técnica y la capacidad, así como el hábitat básico, para conseguir la total recuperación del turón en el medio silvestre. De todos modos, la plena recuperación sólo se puede lograr si las agencias estatales y federales se comprometen firmemente a cumplir los principios previstos por la Ley sobre Especies Amenazadas, y si actuamos para mejorar las condiciones del hábitat en el área de distribución histórica del turón. El presente ensayo crítico ofrece un ejemplo específico de cómo la intervención política ha afectado la recuperación del turón e incluye recomendaciones que, quizás, sean aplicables a la recuperación del lince ibérico y otras especies amenazadas.

Palabras clave
Turón de patas negras, *Mustela nigripes*, perrito de la pradera, programa de recuperación, Ley sobre Especies Amenazadas

Abstract
Once thought to be extinct, a small population of black-footed ferrets (*Mustela nigripes*; ferret) was discovered in 1981 near the town of Meeteetse, western Wyoming. By 1987, only 18 individual ferrets remained, all of which were taken into captivity in an effort to avert extinction and initiate a captive breeding programme. The ferret depends on three prairie dog species *(Cynomys* spp.*)* for survival, and use prairie dogs as prey and prairie dog burrows for shelter and dens. It was the conversion of native grasslands to agriculture and decades of intensive prairie dog poisoning in the 1900s that originally brought the ferret to the brink of extinction. Since 1987, an international ferret recovery programme has overcome significant challenges to experience many remarkable successes. From 1987 to 2007, about 6000 ferrets have been produced in captivity and over 2400 have been reintroduced at 17 separate project sites in the western U.S. and Mexico. Still, reintroduction success varied widely and some efforts were compromised by prey/habitat impacts from an introduced disease *(sylvatic plague)*, drought and politics (with attendant land management failures). The most recent population estimate indicates that wild ferret populations are only about 20% of a long-standing "downlisting" objective (population improvements that would change species status from "critically endangered" to "threatened"). Although the Endangered Species Act and other environmental law in the U.S. provides mandates and guidance for recovery of endangered species, and associated management of federal public lands, perhaps the biggest obstacle to recent recovery progress stemmed from political interference and neglect toward environmental law and policy (as displayed by the U.S. 2000-2008 Administration). The technical expertise, capabilities and raw habitat exist to fully recover the ferret in the wild. However, complete recovery can only achieved with strong recommitments by state and federal agencies to principles set forth in the Endangered Species Act and action to improve habitat conditions over the ferret's historical range. A specific example of how political interference impacted ferret recovery is addressed in this opinion paper, as well as a recommendations perhaps applicable to recovery of the Iberian lynx and other imperiled species.

Keywords
Black-footed ferrets, *Mustela nigripes,* prairie dog, recovery programme, Endangered Species Act

Reintroduction of the Black-footed ferret to the great plains of North America: *Do we really have the capabilities, resources and socio/political will to recover critically endangered species in the United States?* An opinion

Mike Lockhart

Introduction

Dramatic habitat loss and human persecution over decades preceding passage of U.S. Endangered Species Act (16 U.S. C 1531-1544, 87 Stat.884, as amended) caused the near extirpation and/or dramatic decline of many North American wildlife species. After the 1970s disappearance of the last known wild black-footed ferrets (*Mustela nigripes*; ferret) from Mellette County, South Dakota, the ferret was widely regarded as extinct. However, in 1981, another small population was found near the town of Meeteetse, in western Wyoming. Since then, ferret recovery has followed something of a roller coaster track, bringing the species perilously close to extinction by 1987 (when only 18 surviving animals remained and were all brought into captivity), and then to greater stability by 1999, when captive population objectives were first met and substantial progress was made in reestablishing wild populations.

The early history and direction of the ferret recovery programme was accentuated by controversy and sharp management disputes between involved agencies and other parties (Miller et al., 1996). Interpretation of the actual nature, severity and consequences of early programme disputes vary, but despite disagreements and real threats to species survival, significant recovery progress was realized (Lockhart et al., 2006). Indeed, the black-footed ferret programme is now often viewed as something of a model of partnerships and cooperation in endangered species recovery and involves numerous state and federal agencies, Indian Tribes, conservation organizations, and private interests across the U.S., Canada and Mexico. And certainly, since ferrets were relegated to captivity in 1987, the coalition of recovery partners has weathered difficult times to achieve some rather remarkable successes (see previous Endangered Species Bulletin articles; Vol. XXI, No.6; Vol. XXV, No. 3; Vol. XXVII, No.2; Vol. XXVIII, No. 3).

But, where does the black-footed ferret recovery programme really stand today? What are the prospects for downlisting to threatened status, and for full recovery? After years of resigned loss, rediscovery, research, intensive management and numerous advances and setbacks, what lessons have been learned about restoring such a critically endangered species in the face of ever-pressing demands on the natural resources needed to sustain it? These are difficult questions, but necessary to address head-on if recovery challenges are to be overcome.

The black-footed ferret is an obligate carnivore of three North American prairie dog species *(Cynomys* spp.*)* with an original range that largely overlaid prairie dog distribution from southern Canada, through the grasslands and steppes of 12 western states, to northern Chihuahua, Mexico (Figure 1). Although nocturnal, secretive and not well known to science until recent years, the ferret was undoubtedly a numerous and highly successful

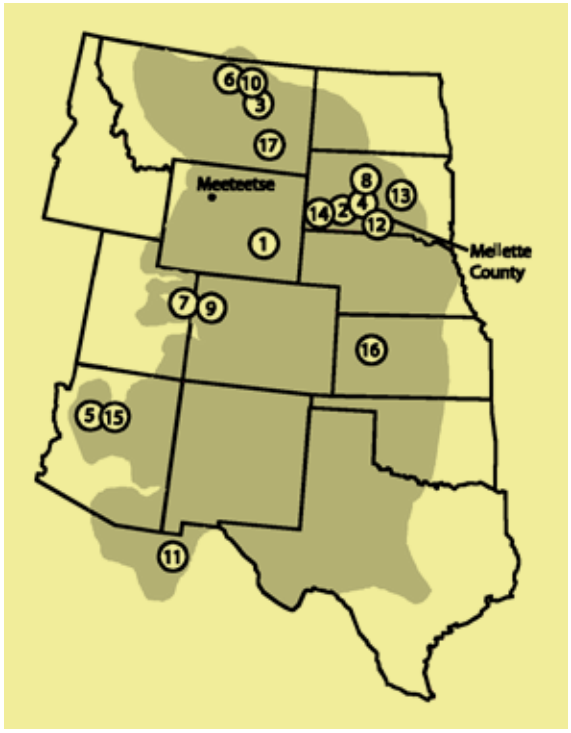

Figure 1. Probable historical range of the Black-footed ferret as defined by composite ranges of black-tailed, white-tailed and Gunnison's prairie dogs (shaded area). The locations of the last extant wild ferret populations near Mellette, County, SD and Meeteetse, WY are also shown. Finally, the locations of specific reintroduction efforts and/or established wild ferret populations are portrayed in their chronological order of implementation as follows: 1) a reintroduced and established wild population in Shirley Basin, WY (1991); 2) a reintroduction effort in Badlands National Park, SD (1994); 3) a reintroduction attempt at UL Bend NWR, MT (1994); 4) a well established wild population in Conata Basin, SD; 5) a reintroduced population in Aubrey Valley, AZ (1996); 6) a reintroduction effort on Fort Belknap Indian Reservation, MT (1997); 7) a reintroduced population at Coyote Basin, UT (1999); 8) a reintroduced and well established population at Cheyenne River Indian Reservation, SD (2000); 9) a reintroduction effort at Wolf Creek, CO (2001); 10) a reintroduction attempt on the BLM "40-Complex", MT (2001); 11) a reintroduced population in Janos, Chihuahua, Mexico (2001); 12) a reintroduced population on the Rosebud Indian Reservation, SD (2003); 13) a reintroduction effort on the Lower Brule Indian Reservation, SD (2006); 14) a new reintroduction effort at Wind Cave National Park, SD (2007); 15) a new reintroduction effort on the Espee Ranch, AZ (2007); 16) a new reintroduction site at Logan County, KS (2007); and, 17) a new reintroduction effort on the Northern Cheyenne Indian Reservation, MT (2008). (From: a revised draft of the Black-footed Ferret Recovery Plan, U.S. Fish and Wildlife Service, unpublished. Some reintroduction sites are doing well, others no longer support ferrets. About 900 ferrets, both kits and adults, were counted on these sites in 2007).

Figura 1. Probable ocupación histórica del turón de patas negras, definida según la combinación de las áreas de distribución de los perritos de las praderas de cola blanca, de cola negra y de Gunnison (área en gris). Las áreas donde existieron las últimas poblaciones de turones en el "Condado de Mellette", Dakota del Sur, y "Meteetsee" Wyoming, también se muestran en el mapa. Finalmente, las áreas de reintroducción y las zonas donde ya existen poblaciones de turones establecidas se muestran en el orden cronológico de los diferentes proyectos de reintroducción: 1) población reintroducida y establecida en "Shirley Basin" (1991); 2) proyecto de reintroducción en el Parque Nacional de "Badlands", Dakota del Sur (1994); 3) proyecto de reintroducción en "UL Bend NWR", Montana; 4) población reintroducida y exitosamente establecida en "Conata Basin", Montana; 5) población reintroducida en "Aubrey Valley", Arizona (1996); 6) proyecto de reintroducción en la "Reserva India de Fort Belknap", Montana (1997); 7) proyecto de reintroducción en "Coyote Basin", Utah (1999); 8) población reintroducida y exitosamente establecida en la "Reserva India del Río Cheyenne", Dakota del Sur (2000); 9) proyecto de reintroducción en "Wolf Creek", Colorado (2001); 10) proyecto de reintroducción en "BLM Complejo-40", Montana (2001); 11) población reintroducida en "Los Janos", Chihuahua, México (2001); 12) población reintroducida en la "Reserva India de Rosebud", Dakota del Sur (2003); 13) proyecto de reintroducción en la reserva india de "Lower Brule", Dakota del Sur (2007); 14) nuevo proyecto de reintroducción en el Parque Nacional de "Wind Cave", Dakota del Sur; 15) nuevo proyecto de reintroducción en el "Rancho Espee", Arizona (2007); 16) nuevo área de reintroducción en el "Condado de Logan", Kansas (2007); y, 17) nuevo proyecto de reintroducción en la reserva india de "North Cheyenne", Montana (2008). (Fuente: borrador revisado del Plan de Recuperación del Turón de Patas Negras, Servicio de Pesca y Vida Silvestre; no publicado. Algunas áreas de reintroducción van progresando bien, mientras que otras ya no necesitan recibir más turones. Aproximadamente 900 turones, incluyendo adultos y crías, fueron censados en conjunto en todas estas áreas de reintroducción en el año 2007).

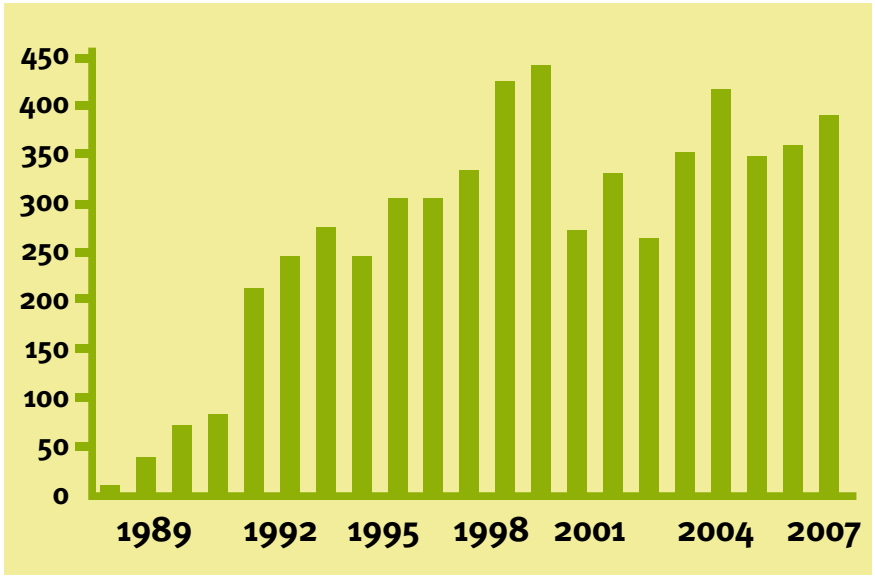

Figure 2. Births of Black-footed ferrets in state and federal breeding facilities and zoos, 1987 to 2007. (Counting ferrets born in a few field breeding programmes, over 6,000 ferrets have been born in captivity since 1987).

Figura 2. nacimientos de turones de patas negras en instalaciones de cría nacionales y en zoológicos entre 1987 y 2007. (Teniendo en cuenta turones nacidos en algunas instalaciones *in situ*, más de 6000 turones han nacido en cautividad entre 1987 y 2007).

species with seemingly inexhaustible habitat and prairie dog prey. That was, of course, before European settlement of North America and eventual conversion of much of the nation's native prairies (and prairie dog colonies) to cultivated lands, and decades of intensive, large scale prairie dog poisoning campaigns waged by western livestock producers over much of the 1900s. While diminished in scope, both factors continue to affect prairie dog populations and limit ferret recovery today! Prairie dogs are still widely regarded as agricultural vermin competitors with cattle for grazing and the cause of rangeland ruin (which is contrary to the evolutionary history of grassland ecosystems and the greater impacts of domestic herbivores, managed pasture systems and drought on range degradation).

The black-tailed prairie dog *(C. ludovicianus)*, the most numerous and widespread of all prairie dog species, suffered the greatest population impacts over the 20th century. The historical range of the black-tailed prairie dog was subjected to extensive habitat conversion and poisoning, resulting in an estimated species population reduction of between 90 and 95% (Forrest, 2005). Impacts to black-tailed prairie dogs were so great that in 2000, the species was designated a candidate for listing as threatened under the Endangered Species Act; a classification later withdrawn by the U.S. Fish and Wildlife Service (USFWS, 2004). Although, new data suggested that the black-tailed prairie dog was not threatened over its historical range, it nevertheless experienced enormous population declines and, with few exceptions, exists today in comparatively small and highly fragmented colonies, colonies largely unsuitable for ferrets.

In addition to threats imposed directly by humans, sylvatic plague (the rodent borne form of bubonic plague) was introduced to the West coast in the early 20th century (via shipboard rats) and has since spread through most western states. Plague has had locally devastating effects on prairie dogs and reintroduced ferrets and is perhaps the single greatest obstacle to ferret recovery today. Only portions of the eastern third of the black-tailed prairie dog range remain free from the effects of sylvatic plague and the entire ranges of the more westerly white-tailed prairie dog *(C. leucurus)* and Gunnison's prairie dog *(C. gunnisoni)* have been impacted.

Thanks to collaborative efforts of numerous state and federal agencies, Indian Tribes, conservation organizations and private partners (many represented on a Black-footed Ferret Recovery Implementation Team established in 1996), ferret recovery has indeed experienced enormous progress. Since ferrets were first successfully produced in captivity in 1987, some 6000 ferrets have been born in Black-footed Ferret Species Survival Plan facilities (six zoos and a Wyoming Game and Fish Department/Fish and Wildlife Service breeding center) and a few field breeding projects (Figure 2). And since 1991, about 2400 ferrets have been reintroduced into Wyoming; South Dakota (six sites), Montana (four sites), Arizona (two sites), two project areas overlaying adjoining portions of northeastern Utah and northwestern Colorado, Kansas and northern Chihuahua, Mexico (Figure 1).

Black-footed ferret reintroduction projects have achieved varying levels of success. The most successful, a reintroduction project covering portions of the Conata Basin district, Buffalo Gap National Grasslands (U.S. Forest Service), and adjoining habitats within Badlands National Park, South Dakota, support a moderately sized and productive wild ferret population. The Forest Service's Conata Basin portion of the recovery area has proven so successful that it is used as a donor site where excess wild-born kits are captured and translocated to start or augment other reintroduction projects. Conversely, several other reintroduction projects have struggled and have, thus far, failed to establish viable populations due to the effects of plague, drought and other habitat constraints.

Steady progress is being made to address biological limitations of wild ferret recovery at the field level. Over the years, a wealth of expertise and capabilities have been developed by programme partners, including some recent and promising results in development of a plague vaccine and other plague management applications. In essence, programme cooperators know how to produce substantial numbers of ferrets in captivity and what is needed to successfully establish wild populations. And it is well demonstrated that, given proper habitat conditions, reintroduced ferrets are capable of rapidly establishing viable, wild populations.

However, that's where the rub in recovery lies today. Presently, there are too few prairie dog complexes (aggregations of colonies distributed about 1.5 km or less from each other) across North America that are large enough, and with suitable densities, to readily support ferret populations. And worse, although there are millions of "unbroken" (uncultivated) hectares of prairie lands with potential to restore prairie dog complexes

and ferret populations, and although there is an enormous base of federal public lands in the west that could be managed more proactively to advance recovery, there remains: 1) a continuing intolerance of prairie dogs by the agricultural community; 2) growing apprehension over sharing lands, especially private lands, with endangered species; 3) an inability to allocate and/or dedicate sufficient financial incentives necessary to develop effective partnerships to offset concerns over managing lands for ferrets and other sensitive prairie wildlife; 4) cumbersome, costly and time consuming administrative processes to establish recovery sites and reintroduction projects, and 5) a growing and troubling trend in devaluing our natural resource legacy in favor of socio-economic factors (especially under the 2000-2008 U.S. Administration).

Recovery events in 2004 exemplified the tenuous nature of ferret recovery; a year which saw high captive breeding output and encouraging progress at reintroduction sites in Arizona, Wyoming, and Cheyenne River Sioux Tribal lands, South Dakota. However, much of the West was also under the grip of an extended drought, and both prairie dogs and ferrets were impacted at reintroduction sites in Mexico, Colorado/Utah and Conata Basin/Badlands, South Dakota. The drought elevated conflicts over forage between cattle and prairie dogs in Mexico and South Dakota. And in South Dakota, the drought caused dispersal of prairie dogs from the highly successful Conata Basin area onto adjoining private lands. That dispersal touched off a fiery political debate and prompted a U.S. Forest Service review of management practices at Conata Basin in an attempt to provide better protections for neighboring ranchers who did not want prairie dogs on their lands.

The process of reducing prairie dog encroachment around Conata Basin included poisoning of prairie dogs both on adjoining ranches and within national grassland "buffer zones" adjacent to private lands, areas which also supported wild ferrets. Although it was unlikely that ferrets were killed from secondary poisoning (the Environmental Protection Agency approved rodenticide, 2%, zinc phosphate bait has limited secondary hazards to carnivores), the added loss of prey in an already drought stressed year undoubtedly increased impacts on ferrets. Moreover, the Forest Service subsequently amended its land use management plan to more assertively promote a "good neighbor" policy that included options for continued lethal control on Forest Service border lands; and more significantly, set the stage for a future plan amendment to control prairie dogs within the heart of the Conata Basin ferret recovery area itself.

The Conata Basin site supports the most successful reintroduced black-footed ferret population to date. Yet, this population is small and still vulnerable (only about 100 breeding adults). Without some ability to offset prairie dog habitat reductions on boundary areas of Conata Basin, and if further restrictions are imposed on natural habitat expansion and prairie dog populations within the core of Conata Basin itself, the full potential of this recovery site would be severely limited and could substantially setback overall ferret recovery prospects. And just recently, an active plaque episode was documented on the southern side of Conata Basin, the worst possible news and gravest management challenge to this increasingly threatened recovery area.

It remains to be seen what effects renewed prairie dog control and plague will ultimately have on the stability and long range potential of the Conata Basin ferret population. However, this issue goes directly to the heart of the most fundamental obstacle in ferret recovery, making room for ferrets and prioritizing long range management of adequate lands and prairie dog complexes to support viable populations of ferrets and other prairie dog associate wildlife species. The current Black-footed Ferret Recovery Plan includes a "downlisting" objective of 1500 breeding adults occupying 10 or more populations scattered over the historical range of the species. And although there have been many reintroduction attempts (Figure 1), the best estimate of the number of wild breeding adults in 2007 is only about 20% of the proposed downlisting objective.

Programme partners have learned that to establish a moderately sized and stable ferret population requires relatively large (in excess of 4050 hectares) and high quality (high density) complexes of prairie dog colonies (even larger complexes in less densely occupied white-tailed and Gunnison's prairie dog habitat). Complexes such as that now found at Conata Basin. From a historical perspective, comparatively huge prairie dog complexes were common throughout the plains of North America and colonies were much more contiguous in distribution. Some complexes occupying tens of thousands of hectares were documented at the turn of the 20th century. However, in our contemporary western landscape, few large complexes remain, especially within the range of the black-tailed prairie dog. And further west, where the largest remaining complexes of both white-tailed and Gunnison's prairie dogs are found, periodic epizootics of sylvatic plague hold back ferret recovery potential.

Moreover, what 2004 taught us is that our most basic measure of prairie dog/ferret habitat (total area of occupied prairie dog habitat), is itself a highly dynamic and somewhat ineffective gauge of habitat quality and stability. In response to extreme drought conditions and limited forage at Conata Basin, prairie dogs were forced to disperse over a larger area, and the area of occupied prairie dog colonies swelled from about 6880 hectares to over 9300 hectares (Livieri and Perry, 2005). Yet, both prairie dog and ferret densities were stretched thin and reproduction of both suffered (Livieri and Perry, 2005). Consequently, prairie dogs, which unlike cattle are not constrained by fences and can more effectively spread foraging activity over drought-impacted lands, again became the focus of a long-standing debate and a convenient scapegoat for poor range conditions: impacts more reasonably attributed to the effects of cattle grazing and the drought itself. Habitat conditions substantially improved in 2005 with increased rainfall, yet the battle over prairie dogs and ferret recovery in Conata Basin goes on and significant threats to the recovery programme's premier reintroduction site persist.

Enormous resources have been vested in ferret recovery over the past two decades and with great success. And many programme partners believe we possess both the expertise and technical ability to fully recover this species. Moreover, compared to the vastness of lands potentially available for ferret recovery, the amount of habitat actually needed to meet population objectives represents a tiny, tiny fraction of the western landscape. In an upcoming revision of the Black-footed Ferret Recovery Plan, a delisting target of 3000 breeding adults is being considered. On average, adult ferrets occupy some 80 hectares of habitat. Consequently, only about 243,000 hectares of stable prairie dog habitat across the western states would be needed to meet such a recovery objective. Put in perspective, that is about one percent of the estimated 153 million hectares of "potential" prairie dog habitat that remains in the U.S. (Ernst, Clark and Gober, 2006).

The Forest Service's National Grassland units alone support more than 1.4 million hectares of public lands from Montana and North Dakota, south to Texas and New Mexico. The Forest Service manages more plague-free, black-tailed prairie dog habitat than any other federal agency. And yet, less than 1% of the National Grassland land base is currently involved in an active ferret recovery effort: Conata Basin, which as noted above is under considerable threat. Perhaps no other agency has more ability (and hence responsibility) to foster ferret recovery in the wild today than the Forest Service. But instead of moving recovery efforts forward, as outlined in an original 2002 Forest Plan revision for the entire northern Great Plains, the Forest Service has apparently succumbed to local political will and has largely reversed some favorable prairie dog and ferret management decisions contained in that plan. Indeed, in a pending Land Use Management Amendment for grassland units in Nebraska and South Dakota, covering over 283000 hectares of public land, the Forest Service could artificially cap the amount of occupied prairie dog habitat to only 3%. The multiple-use concept of federal management and associated commitment for the conservation of declining and endangered prairie species appears grossly out of balance on Forest Service lands today.

It is important to understand that ferret presence does not foreclose other land uses. Ferrets are not sensitive to human activities and disturbance, and as long as base habitat conditions are maintained (i.e. sufficient prairie dog numbers), ferret populations can exist in harmony with livestock grazing, oil and gas development, hunting, other recreation, etc. Grazing is in fact of integral importance in managing prairie wildlife communities, including prairie dogs and ferrets. However, ferret recovery cannot be achieved by attempts to force-fit the species into small parcels of habitat grudgingly conceded as acceptable to other land use interest groups. Nor can we realistically recover the ferret, if the islands of prescribed recovery habitat are themselves compromised whenever drought or other factors overwhelm our willingness to maintain priority management for prairie dogs over other forms of temporal competition (i.e., grazing). For example, after chronic plague episodes compromised a ferret reintroduction effort in north central Montana, the U.S. Bureau of Land Management overturned the management of habitats set aside for prairie dogs and ferrets. Recreational shooting of prairie dogs was again allowed in those areas even as prairie dog populations struggle to recover. Without long range commitments to prairie dog conservation and expanded efforts to block-up lands for even larger prairie dog complexes, regardless of their present status, the eventual recovery of the ferret becomes increasingly problematic.

And so, given current world events and societal pressures, just how much of a national priority is the recovery of species like the black-footed ferret? To many partners directly involved in ferret recovery, we not only see the value of restoring and safeguarding this beautiful, interesting and highly specialized carnivore itself, but the

biological imperative of maintaining a good distribution of intact prairie/steppe ecosystems, lands to sustain natural biodiversity and populations of prairie dogs, ferrets, swift foxes, ferruginous hawks, burrowing owls, mountain plovers and a wide array of other wildlife species dependant on declining native grasslands. This is, after all, one of the fundamental tenets of the Endangered Species Act itself.

And what lessons have we really learned over the past 22 years since the last wild ferrets from Meeteetse, Wyoming were taken into captivity? The black-footed ferret can indeed be fully recovered. But it will require a recommitment of principles and resources to secure habitats, and the cooperation and support of those who would share lands with ferrets. To build on the notable successes of the ferret programme, the USFWS and its many involved partners must reexamine and amend basic administrative and management approaches to recovery. They need to become more proactive, responsive, and flexible in development of reintroduction projects while eliminating the fear of impacts on adjoining, non participating land owners. Although substantial progress has been made in this area over the past two years, political challenges remain. A series of National Wildlife Refuges are needed to conserve substantial segments of highly diverse and threatened prairie ecosystems in support of endangered and declining grassland species. Vast USFWS refuge holdings (over 38 million hectares) have been established for the protection of wetland habitats and associated wildlife values, game species and the recovery of certain endangered species. However, no National Wildlife Refuge lands exist today that could potentially support large prairie dog complexes. Also, ferret recovery should be spread over all states within the historical range of the species, recovery efforts should be focused on federal public lands (wherever possible); smaller "nursery" recovery sites (habitats perhaps too small to support self-sustaining ferret populations, but may persist with periodic augmentation) should be developed in plague-free areas, and more effective assistance/incentive programmes are needed to promote management of larger prairie dog complexes on both private and Indian Tribal lands.

Do we have that kind of resolve and can we overcome the prevailing sentiments of "not in my backyard"? Are we willing to actually dedicate the resources necessary to fulfill mandated ferret recovery responsibilities? Unfortunately, the answer to these questions at the present time, and especially under the direction and management of the 2000-2008 Administration, appears to be "no". And so, the roller coaster ride continues and as a nation the U.S. is up against the very socio-economic and political issues that caused the original decline of the black-footed ferret, factors which will ultimately determine the fate of this and other declining and endangered species, and will test our country's will to preserve our native wildlife heritage. It would be an unforgivable indictment for such a progressive and value-based society as ours to squander the significant recovery gains made to date and let the black-footed ferret slip back into oblivion or be denied a secure, wild future across the western plains of the U.S., Canada and Mexico (Figure 3).

Finally, what are the major lessons from ferret recovery efforts that can be applied to other imperiled species, such as Iberian lynx *(Lynx pardinus)*? First, for species reduced to such critically low numbers that complex captive breeding programmes are required, much of the available recovery resources and attention are necessarily focused on captive breeding itself. However, such concentrated effort often comes at the expense of important, long range work needed to restore native habitats and/or prey necessary for eventual wild recovery. In tragically backwards rationale, U.S. politicians and federal land managers over the past few years have used the success of the ferret captive breeding programme as justification to postpone or avoid essential land use decisions needed to promote ferret habitat enhancement. Prevention of extinction is not species recovery and the restoration of stable wild populations and biodiversity requires much greater, long-standing commitments to reduce those factors that cause and/or sustain species decline, and for development of adequate reintroduction refugia. Moreover, the ability to restore viable populations of locally extirpated species becomes increasingly difficult as native habitats are progressively compromised by other, often incompatible, land use practices. Concomitant decisions for both captive breeding and aggressive habitat/prey conservation programmes are therefore essential in the earliest possible stages of recovery project development.

Second, the conservation and management of endangered species is often fraught with controversy and disagreements between a variety of government, academic, and private advocates and adversaries. Most involved parties would agree that the early stages of development of a ferret recovery programme were heavily encumbered by individual disputes and agency parochialism. It is extremely important then to develop a collaborative and

Photo: Mike Lockhart

Figure 3. Biologist Jesus Pacheco, University of Mexico, releases as captive reared and preconditioned black-footed ferret at a reintroduction site in northern Chihuahua, Mexico.

Figura 3. El biólogo Jesús Pacheco, de la Universidad de México, suelta un turón de patas negras criado en cautividad y "entrenado" para su reintroducción, en un espacio de reintroducción en el norte de Chihuahua, México.

transparent management framework that has the support of the highest levels of national, state and provincial governments. Although the USFWS has ultimate authority in the U.S. for decisions related to endangered species recovery, management advice and direction for ferret recovery is largely provided by a Black-footed Ferret Recovery Implementation Team (BFFRIT). The BFFRIT is comprised of 27 involved state and federal agencies, Indian Tribes and conservation organizations, and is further divided into four subcommittees with responsibilities for policy direction, field conservation, captive breeding, and education and outreach. Although overall recovery efforts can be, and are, affected by political influences (especially under the constraints of the 2000-2008 U.S. Administration), the BFFRIT provides guidance on all elements of ferret recovery and has been instrumental in reducing intra-programme conflict. In administering the BFFRIT, the USFWS encourages broad and innovative approaches to implementation of captive breeding and reintroduction projects, solicits partner views on proposed research and ferret allocations (for reintroduction and research purposes) and fully responds to all comment and input provided by BFFRIT members in making final decisions. The development of such an open and collaborative management process resulted in correspondingly rapid progress toward ferret recovery and continues to be an effective vehicle for promoting the conservation of prairie habitats for ferrets and a host of other declining native grassland species.

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Losers live in the past. Winners learn from the past and enjoy working in the present toward the future.

Denis Waitley

Photo: Alexander Sliwa

Planning of veterinary supervision for translocation programmes of wild felids

Planificación de la supervisión veterinaria en programas de translocación de felinos silvestres

Marie-Pierre Ryser-Degiorgis

Resumen

Los riesgos de enfermedad en los proyectos de translocación y reintroducción se pueden resumir principalmente en dos tipos de escenarios, que en ambos casos afectan a los animales a translocar, a otros animales silvestres, al ganado doméstico, a mascotas y a seres humanos. Estos dos escenarios son: 1) la introducción por los animales reubicados de un patógeno en el entorno de destino y 2) la transmisión de un patógeno que sea nuevo para los animales a reubicar durante el proceso de translocación o procedente del entorno de destino. Para cuantificar y minimizar los riesgos sanitarios que son inherentes a la translocación de animales se necesitan medidas veterinarias apropiadas. Las evaluaciones veterinarias deben realizarse tanto a nivel individual como a nivel del ecosistema. La evaluación de los riesgos de enfermedad o para la salud consisten en la aplicación del sentido común para valorar si la translocación de los animales pueda implicar riesgos significativos relacionados con la salud, a sabiendas de que es imposible trabajar sin riesgo alguno. Para identificar los posibles riesgos para la salud hay que tener en cuenta tres aspectos: 1) la susceptibilidad a la enfermedad y posible papel portador de la especie a reubicar; 2) la presencia de patógenos y otros problemas potenciales para la salud en el entorno de origen, y 3) la presencia de patógenos (o de compuestos tóxicos) en el entorno receptor.

La documentación científica correcta es casi tan importante como la evaluación de riesgos para la salud. Cada uno de los ejemplares, tanto vivos como muertos, es una fuente valiosa de información para el presente y para el futuro. Por consiguiente, se debe poner mucho énfasis en el muestreo amplio y en la recopilación de información.

Las decisiones acerca de si hay que proceder o no con las traslocaciones de animales silvestres pueden estar determinadas por los resultados de la evaluación de riesgos para la salud, los recursos, los aspectos logísticos, sociopolíticos y por cuestiones de conservación. Teniendo en cuenta que los

recursos suelen ser limitados, es necesario establecer prioridades. Además, es imprescindible determinar cuáles son los resultados necesarios para decidir si un animal puede ser reubicado o no. Una vez finalizada la evaluación de riesgos para la salud y determinadas las prioridades, se pueden proponer los protocolos correspondientes. Es necesario un enfoque multidisciplinario durante las fases de planificación e implantación. Asimismo, es imprescindible que todo proyecto sea considerado como un proceso flexible: hay que intentar reducir al mínimo las pérdidas y los problemas, pero en caso de que ocurriesen, hay que aprender de ellos y adaptar los procedimientos debidamente.

Palabras clave
Evaluación de riesgos para la salud, enfermedad, documentación, patógeno, prioridades, protocolos, reubicación

Abstract
Appropriate veterinary measures are required to quantify and minimise the health risks that are inherent in the translocation of animals. Veterinary considerations should be addressed both at the individual level and at the ecosystem level. Disease risks in translocation and reintroduction projects can be basically summarized in two main scenarios, both involving the animals being translocated, other wildlife, domestic livestock, pets, and humans: 1) introduction of a pathogen into the destination environment by the animals being translocated and 2) transmission of a pathogen that is new to the animals being translocated during the translocation process or from the destination environment. Disease or health risk assessment (HRA) is the application of common sense to evaluate whether or not important health-related risks are associated to the translocation of animals, acknowledging that it is impossible to work without any risk. To identify potentially associated health hazards, three points need to be considered: 1) disease susceptibility and potential carrier role of the species to be translocated; 2) presence of pathogens and other potential health problems in the source environment, and 3) presence of pathogens and other potential health problems (including toxic compounds) in the destination environment.
Adequate scientific documentation is almost as important as HRA. Every single individual, alive or dead, is a valuable source of information, for the present and for the future. Thus, emphasis should always be placed on extensive sampling and information collection. Decisions on whether or not to proceed with wild animal translocations may be determined by the results of HRA, resources, sociopolitical aspects, logistics and conservation issues. In this regard, and since resources are usually limited, priorities have to be set. Amongst others, it is essential to establish clear criteria to decide what are the minimum standards to render an individual acceptable for translocation –i.e., what are the key agents to be tested for– before deciding whether an animal can be translocated or not. As a next step, suitable protocols can be proposed. A multidisciplinary approach is required both during the planning and the implementation stages. Also, it is essential to consider these projects as adaptive processes, i.e., to learn from results and adjust the methodology accordingly.

Keywords
Health risk assessment, disease, documentation, pathogen, priorities, protocols, translocation

Planning of veterinary supervision for translocation programmes of wild felids

Marie-Pierre Ryser-Degiorgis

Introduction

Translocations are defined as the intentional movement of animals and their release into the wild in an attempt to reintroduce a species in an area which was once part of its historical range, to supplement an existing low density native population or to introduce a species outside of its recorded distribution (IUCN, 1998). Translocations are thus an important tool in wildlife conservation and management (Figure 1).

The success of translocation projects depends on several factors. Besides non biological and biological considerations, such as local support together with the choice of a suitable habitat with sufficient and appropriate food resources in the release area, health aspects play a crucial role in wildlife translocation and reintroduction strategies. Indeed, the veterinary implications of projects involving the movement of wild animals, even over relatively short distances, are sometimes unexpected (Woodford and Kock, 1991).

Appropriate veterinary measures are required to quantify and minimise the health risks pertaining to the translocations of animals, and to ensure the health and wellbeing of released stock throughout the length of the Programme (IUCN/SSC, 1998; Woodford and Rossiter, 1993; Kock et al., 2007). Disease risks in a translocation project can be basically summarized in two main scenarios: 1) Introduction of a pathogen into the destination environment by the animals being translocated. Relocation of wild animals never consists of the movement

Photo: Andreas Ryser

Figure 1. Release of a translocated Eurasian lynx.

Figura 1. Suelta de un lince eurasiático en un proyecto de translocación.

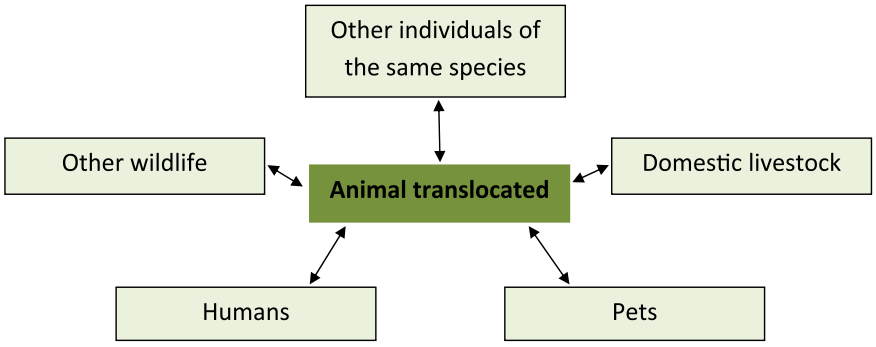

Figure 2. Intra- and interspecific interactions to be considered for health risk assessment.

Figura 2. Interacciones intra e interespecíficas que deben tenerse en cuenta en una evaluación de riesgos sanitarios.

of a single species, rather, it always entails relocation of a "biological package" consisting of the animal itself and its passenger organisms such as parasites, viruses, bacteria and fungi (Davidson and Nettles, 1992). 2) Transmission of a pathogen new to the animals being translocated during the translocation process or from the destination environment. In both cases, pathogen transmission has to be considered between the animals being translocated and other wildlife, domestic livestock, pets and humans (Figure 2). All of them can be healthy carriers and/or potential victims of pathogens. Thus, for a health risk assessment, it is necessary not only to consider diseases affecting the species of concern, but also the infectious agents that the translocated animals could potentially pass on to other animal populations or even to humans.

Veterinary considerations should be addressed both at the individual and at the ecosystem level. In the first case, the aim is to maximize the survival of each single individual to be translocated, which is essential for the success of the project. Safe and effective anaesthesia, stress management, wound treatment, and individual health screening are crucial at this level. Clinically healthy animals are not necessarily pathogen-free (Cunningham, 1996) and thus, capture, transport and change of environment –which are always a source of enormous stress– may affect animals in various ways; e.g., in predisposing them for the development of a disease (Woodford, 2001; Teixeira et al., 2007). Furthermore, animals can get wounded during capture or transport and may require medical treatment. And last but not least, animal welfare considerations have to be taken into account (IUCN, 1998; Woodford, 2001). At the ecosystem level, the aim is the prevention of the movement of pathogens through the movement of animals, since the movement of pathogens to new environments may have important effects on wildlife, agriculture or public health, and may affect the translocation effort itself (Leighton, 2002). This implies detailed disease risk assessment in both the source and destination environments, as well as individual health screening procedures.

A thorough planning of the veterinary supervision is a necessity. However, not only health concerns, but also further factors such as biological, political and scientific considerations will influence the veterinary protocols (Figure 3; Jiménez, this book). A multidisciplinary approach is therefore required both during the planning and the implementation stages (Woodford & Kock, 1991). All involved staff must be consulted for decision making, and potentially critical situations that may occur during the project have to be discussed prior to taking action.

Health risk assessment

Disease or health risk assessment is the rigorous application of common sense to evaluate whether or not important health-related risks are associated with a proposed activity, such as the translocation of animals (Leighton, 2002). Health risk assessment requires a detailed translocation plan, and the subsequent identification of associated health hazards, both in the source and destination ecosystems. For this purpose, a comprehensive list of potential health hazards has to be provided. This includes three important steps (Figure 3).

Disease susceptibility and eventual carrier role of the species to be translocated

All existing information on the species needs to be gathered, including published and unpublished reports or personal observations. Known causes of morbidity and mortality, potential sources of infection, performed

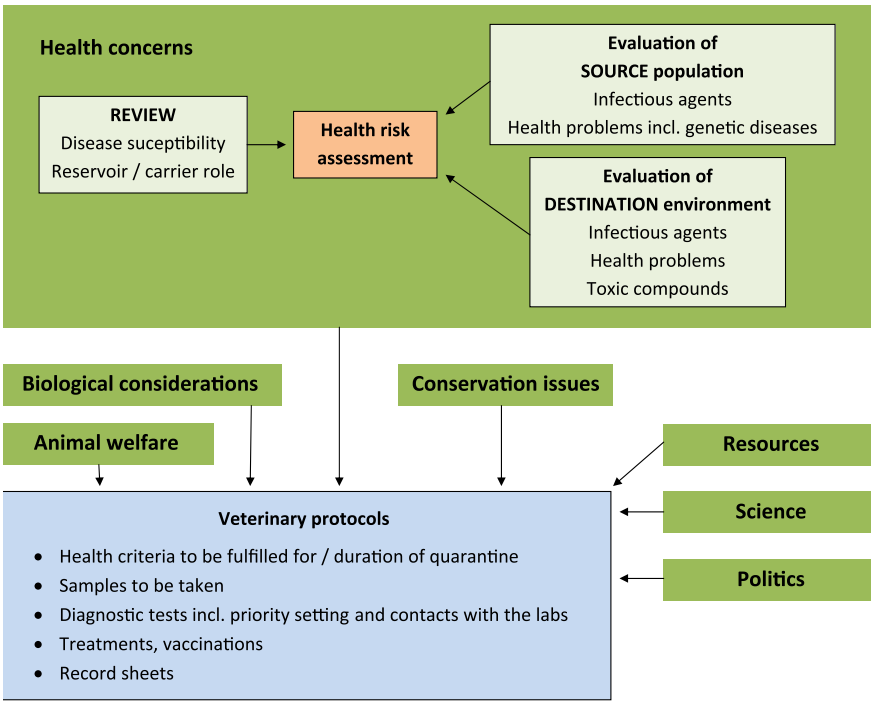

Figure 3. Factors to be considered for the planning of the veterinary supervision of a reintroduction/translocation project and when proposing protocols.

Figura 3. Factores a considerar durante la planificación para la supervisión veterinaria de proyectos de reintroducción/translocación, así como durante la propuesta de protocolos.

serological surveys, epidemiological relationships with other species, persistence of relevant infectious agents in the environment, their pathogenicity and routes of transmission are all important information to be considered. The compiled data must be organized in a database and presented in a detailed written review. In this way, the knowledge on the species at the time of project planning is well documented and available for all concerned participants, facilitating discussions regarding veterinary procedures.
In this context, it should be noted that if no diseases are recorded for the species in question, it does not mean that this species is not susceptible to diseases (Cunningham, 1996).

Presence of pathogens and other potential health problems in the source environment.
Knowledge regarding the health status of the source population(s) (captive or free-living) is essential to evaluate the risk of "pathogen translocation" and of "translocation" of non infectious health problems such as genetic defects. Therefore, data need to be collected on the infectious agents and diseases present in the source ecosystem, i.e., all available information concerning causes of death, infectious and non-infectious diseases, and carrier status of the concerned population(s) –post-mortem investigations, epidemiological surveys, etc.– must be compiled and taken into account during the planning process.

Presence of pathogens in the destination environment
The presence of pathogens that could entail a risk for animals being translocated (according to the abovementioned review) has to be assessed in the release area. Such pathogens might be present in other wildlife species, or in domestic stock and pets that live within the surrounding area. Furthermore, the presence of infectious agents that may be introduced by translocated animals has to be investigated, both in the species of concern (in case of re-stocking) and in the associated fauna. In this second scenario, pathogens that are already present in the area do not necessarily need to be considered, while those that are absent would require more attention. In addition, it is important to assess the presence of toxic substances in the environment (e.g. pollutants, poison distributed for control of pest species, etc.) that could affect the animals targeted for translocation.

The pathogenic potential of infectious organisms can basically be classified into three categories: 1) pathogenic, for those known to produce disease; 2) non-pathogenic, for those studied well enough to determine that they never produce illness, and 3) unknown, for those where there is insufficient information to evaluate their pathogenicity. However, risk assessments are not absolutely predictable, especially since biological factors in the release areas might favour "exotic" pathogens normally considered harmless, thereby producing unpredictable disease syndromes (Davidson and Nettles, 1992).

Since an assessment of the health risk of each identified hazard is almost never feasible, it is necessary to select a small number of hazards that appear to have the greatest potential to pose important health risks. Risk must be then completely and rigorously estimated for each selected health hazard, i.e., the probability that the hazardous event will occur and the magnitude of the consequences that may result if such event does occur (Leighton, 2002). It is important to note that it is impossible to work without taking any risks. The aim is to minimize them as far as possible, but one has to keep in mind that a certain risk will always remain.

Scientific documentation and sample archives

Disease risk assessment is of central importance in the veterinary supervision of translocation projects. Yet, especially when dealing with an endangered species, adequate scientific documentation of the project implementation –including individual veterinary records– is crucial. Conservation projects imply a significant amount of manpower and financial investment. Every single individual, alive or dead, is a truly valuable source of information, for the present and for the future. Thus, even if disease risk assessment reveals that there are no diseases of concern in the frame of the translocation project, emphasis should still be placed on extensive sampling and information collection.

On the one hand, all procedures, results from physical exams, complementary diagnostic tests and laboratory analysis need to be recorded in detail. Data on pathogens that are apparently not influencing the health status of the animals should, as far as possible, also be collected in order to learn about the species and about the pathogens.

On the other hand, biological samples should be stored for eventual retrospective studies. For example, an apparently emerging pathogen that was not considered at the time of translocation might be detected in the release area several years after translocation. If appropriate samples of the translocated animals have been stored, it will be possible to use them for a retrospective analysis in order to determine whether the translocated animals were already infected with this apparently new pathogen at the time of translocation.

Priority setting: decision-making vs. documentation

Within the frame of any project, priority-setting is key, since human and financial resources are often limited. This has to be done for every single aspect of the project, including the health criteria for the selection of animals for the translocation programme, the length of the quarantine period, and the individual health screening protocols (Figure 3). Decisions whether or not to proceed with wild animal translocations may be determined by the results of health risk analysis, but they also may be influenced by a variety of other factors such as political and/or conservation issues. Health risk analysis informs decision makers regarding potential health risks and provides them with options to reduce risk if it is decided to proceed with the translocation (Leighton, 2002). For example, in case of a highly endangered species, it might be very difficult to capture animals for translocation that are free of any pathogen that could represent a risk for another, widely distributed species in the destination environment. If this risk appears to be rather low, the conservation goals of animal translocation might be of higher priority than the avoidance of introducing pathogens into the destination environment.

Furthermore, it is fundamental to differentiate between optimal and minimal –or essential– requirements. It is always interesting to perform testing for numerous infectious agents in all animals. However, it is necessary to establish clear criteria to decide which are the minimum standards to render an individual acceptable for translocation. The selected key agents should have first priority, and the tests should be done as soon as possible. All other infectious agents will have second priority, i.e., the needed samples will be taken, but only analyzed according to the laboratory capacity and the financial resources. No simple guidelines can cover all situations. Each species, each geographical area, each project is a case in itself and must be evaluated separately, taking into account all biological, ecological, geographical and epidemiological circumstances (Woodford and Rossiter, 1993).

Table 1. Check list for veterinary procedures in the frame of translocations projects.

Tabla 1. Lista de comprobación de los procedimientos veterinarios en el marco de los proyectos de translocación.

• Disease risk assessment	
• Health criteria for inclusion into the translocation programme	
• Options if the health criteria are not fulfilled*	
• Considerations of the legal and veterinary restrictions on translocation of wildlife	
• List of duties of the field veterinarian(s)	
• List of material:	
	Immobilization
	Physical exam
	Pharmacy
	Record sheets (physical exams, anaesthesia, quarantine, transport, post-mortem)
	Individual record sheets and boxes for sample shipment
• Telephone list:	
	Project veterinarians
	Laboratories
	Animal hospital
	Quarantine station
	Field biologists
	Project leader
	Responsible authorities
• Sampling:	
	Required samples (e.g. blood, faeces, swabs)
	Sampling methods
	Collaboration with laboratories
	Priority list for analysis
	Preservation
	Shipment
• Capture (in the wild or in captivity):	
	Anaesthesia protocol
	Health screening (physical exam, sampling)
	Complementary diagnostic tests (radiography, ultrasound, etc.)
	Treatment (e.g. against parasites), vaccination
	Identification
• Transport (from capture site to quarantine station, and from quarantine station to release site):	
	Design of transport boxes
	Vehicles
• Heating/cooling of vehicle according to the temperature:	
	Anaesthesia / tranquillization
	Animal monitoring
	Paperwork (e.g. official health certificates, transport documentation)
• Quarantine:	
	Duration**
	Location
	Isolation of animals (other species, humans)
	Design of facilities (size of enclosures, structure)
	Diet (type of food, sources, frequency)
	Hygiene (incl. disinfection after release)
	Observation (e.g. camera surveillance)
	Use of tranquillizers
	Medical records
• Release:	
	Procedure for re-captures in the enclosure
	Pre-release physical exam
	Sampling
	Treatments, re-vaccination
• Post-release monitoring:	
	Health screening and sampling protocol for captures
	post-mortem protocol

*** Release in the source area, treatment, euthanasia, collaboration with a veterinary clinic or a rehabilitation center.**
**** Minimal requirements, considering both the goals of the quarantine and the fact that it is a stressful situation for animals coming from the wild.**

*** Suelta en el area de origen, tratamiento, eutanasia, colaboración con clínicas veterinarias o centros de rescate de fauna.**
**** Requerimientos mínimos, consi–derando tanto los objetivos de la cuarentena como el hecho de que es una situación estresante para los animales que provienen de la naturaleza.**

Photo: Andreas Ryser

Figure 4. Examination under field conditions of a Eurasian lynx caught for translocation. At first, vital signs are recorded by the veterinarian of the capture team.

Figura 4. Examen en condiciones de campo de un lince euroasiático capturado para su translocación. En primera instancia, el veterinario del equipo de captura debe registrar las constantes vitales del animal.

Protocol proposals

Once a health risk assessment has been performed and priorities have been set, suitable protocols can be proposed. Reduction of health risks identified in the risk assessment may be achieved by changing some of the translocation procedures, such as choice of source and destination environments, methods of capture, transportation, quarantine and release of animals, and veterinary procedures such as immobilization protocol, disease testing, therapeutic treatments and vaccinations (Leighton, 2002).

Clear procedures are essential to avoid confusion, destructive emotions and stress situations in case of problems. Procedures should therefore be proposed in advance for each potential worst-case scenario. Furthermore, the project has to be considered as an adaptive process: protocols should be regularly re-evaluated in order to improve them if necessary (see Shenk, 2001). Overall, veterinary planning must take into account a number of points, which are summarized in Table 1. A comprehensive checklist for health risk analysis and protocol development is provided by the Office International des Epizooties and the Canadian Cooperative Wildlife Health Centre (Anonymous).

The following aspects are of particular concern in wild cats. At physical examinations (Figure 4), particular attention should be given to claws, footpads, teeth, and gums. Split claws and abraded pads are hard to observe in conscious animals. Dental problems, such as fractured teeth with pulp exposure, are common problems in captive non-domestic cats and severe cases could be life-threatening due to a potentially secondary systemic disease (Roelke et al., 1991; Blomqvist et al., 1999; Ryser-Degiorgis et al., 2002; Ryser-Degiorgis, this book). Once in quarantine, newly arrived individuals might refuse to eat as a result of the stress caused by the changes in their environment (Roelke et al., 1991; Blomqvist et al., 1999; Ryser-Degiorgis et al., 2002). Freshly killed, whole animals with the abdominal cavity opened can provide an effective feeding stimulus to some cats (Blomqvist et al., 1999). Although a minimal duration of 30 days is generally recommended for the quarantine of non domestic cats (Blomqvist et al., 1999, Woodford, 2001), animal husbandry issues (e.g., stress in captivity) may require that the quarantine period be shortened (Woodford, 2001; Ryser-Degiorgis, unpubl. obs.). There are thorough overviews of common pathogens to be included in the health screening protocols of non domestic cats, and recommended vaccinations and anti-parasitic treatments (Blomqvist et al., 1999; Woodford 2001). Further general information on diseases of non-domestic felids is reported by Terio et al. (this book) and Munson et al. (in press). For transport, animal welfare is a prime consideration. It is not necessary to provide food and water on short journeys (Blomqvist et al., 1999). Crates and boxes must be large enough to meet the relevant regulations and strong enough to contain the species concerned. Recommendations for the design of transport boxes for wild cats are presented in Blomqvist et al. (1999). A crated felid should be left in quiet, dimly lit surroundings and the attention of curious bystanders kept to a minimum (Blomqvist et al., 1999; Ryser-Degiorgis, 2002). Excited cats overheat very easily in confined spaces.

Post-release veterinary monitoring

For a complete, long-term evaluation of the health situation in particular and of the success of the translocation project in general, veterinary data must also be recorded *after* release (health screening at captures, reproductive success, causes of mortality, archiving of samples; e.g., Wild et al., 1999; Shenk, 2001; Wild et al., 2006). Losses of single individuals in small populations can have a significant impact on future population characteristics. Furthermore, even if epidemics are considered improbable, they still can play an important role in the long-term viability of a population (Ballou, 1993). Valuable information can be gained from blood samples, faecal samples, and post-mortem material (Blomqvist et al., 1999).

Photo: Marie-Pierre Ryser-Degiorgis

Figure 5. Eurasian lynx in a quarantine enclosure. Small, healed superficial wounds that resulted from the capture in a box trap are visible on the forehead and nose of the animal.

Figura 5. Lince euroasiático en instalaciones de cuarentena. El animal presenta pequeñas heridas superficiales en la frente y la nariz, que resultaron del proceso de captura en jaula trampa.

Learning from experiences

Many reintroduction projects have been poorly documented (von Arx et al., this book). In order to learn from experiences and to allow for a long-term approach to conservation, documentation is essential (Breitenmoser et al., 2001). Hence, all recorded data should be maintained in a database and presented in written reports, ideally in form of internationally available publications. Information such as anaesthesia protocols that are considered safe and efficient, reference data for the species (e.g. haematology, biochemistry), evaluation of capture methods (stress, injuries; Figure 5), observed infectious agents (serology, PCR, parasitology), diseases, behavior in quarantine (including problems in the enclosures), and encountered difficulties throughout the process, represent important information to be recorded and shared.

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Photo: Alexander Sliwa

Seek simplicity – and, having found it, suspect it.

James Conant

Photo: Ignacio Jiménez

Non-biological aspects to be considered in endangered species recovery programmes

Aspectos no biológicos en programas de recuperación de especies amenazadas

Ignacio Jiménez

Resumen

El propósito de este capítulo es resaltar la importancia de los factores de tipo no biológico en cualquier programa de conservación de especies amenazadas, con énfasis en aquéllos que tienen un componente *ex situ*. A la hora de manejar este tipo de programas, se debe tener en cuenta que la supervivencia final de la población que tratamos de conservar se ve últimamente influenciada por cómo la sociedad en general percibe y prioriza el problema de su conservación y por cómo nos organizamos los profesionales de la conservación para evitar la extinción de una especie.

Cualquier programa de recuperación que tenga cierta relevancia pública involucra a un conjunto numeroso y diverso de actores con identidades, perspectivas, demandas y recursos claramente diferenciados. Resulta crucial tener una visión lo más completa posible de este contexto social para gestionarlo eficientemente, evitando bloqueos interinstitucionales y conflictos destructivos. Aunque el conflicto tiende a ser visto como un proceso negativo, si se maneja adecuadamente, puede convertirse en una fuerza creativa de mejora constante de un programa. Para lograr esto, se propone: 1) incentivar el desarrollo de relaciones colaborativas frente a otras más competitivas entre proyectos e instituciones; 2) incluir a profesionales en gestión de conflictos dentro de los programas de conservación, y 3) fomentar el amplio reparto de recursos no distributivos. Igualmente, se destaca la importancia que los aspectos organizativos pueden tener sobre la recuperación de una especie amenazada. En este sentido, se propone: 1) desarrollar procesos de planificación colaborativa; 2) incentivar la creación de equipos de trabajo efectivos adecuadamente liderados y con capacidad de trabajo sobre el terreno; 3) evitar que las estructuras de control institucional detengan el desempeño de acciones concretas y necesarias sobre el terreno, y 4) identificar y minimizar procesos de desplazamiento de objetivos. Finalmente, se hace una llamada a la múltiple y frecuente evaluación de los programas de recuperación de especies amenazadas para asegurar su mejora constante y sistemática.

Palabras clave

Contexto social, gestión de conflictos, aspectos organizativos, desplazamiento de objetivos, equipos de conservación, evaluación de programas

Abstract
This chapter seeks to highlight the key influence of non-biological issues in any recovery programme, with an emphasis on *ex situ* conservation. When managing a recovery programme, we need to be aware that the final survival of any population of concern will be ultimately determined by how society perceives and prioritises its conservation, and by how professional conservationists organize themselves to avoid its extinction. Any conservation programme of public relevance involves a complex arrangement of stakeholders with distinct identities, perspectives, demands and resources. It is key to achieve a clear picture of this social context in order to manage it effectively, and to avoid inter-institutional gridlocks and destructive conflict. Even though conflict tends to be perceived as a negative process, when properly managed it can become a creative force, encouraging programme improvement. To achieve this, I propose to: 1) include professionals with experience in conflict management within conservation programmes; 2) promote the establishment of collaborative instead of competitive relationships between projects; and 3) encourage the open exchange of non-distributive values. Organizational issues can exert a significant influence on species recovery. In this regard, I propose to: 1) develop collaborative planning processes; 2) establish on the ground teams with effective leadership and strong capabilities; 3) avoid institutional arrangements focused on process control, which end up hindering actual implementation of necessary actions, and 4) identify and defuse goal displacement processes. There is a final call for multiple and regular evaluation of recovery programmes to promote constant and systematic improvement.

Keywords
Social context, conflict management, organizational issues, goal displacement, conservation teams, programme evaluation

Non-biological aspects to be considered in endangered species recovery programmes

Ignacio Jiménez

Integrated approaches for *ex situ* conservation?

Most readers would not be surprised when hearing that endangered species recovery is a complex challenge consisting of biological, ecological and health issues, compounded by social, organizational, political, economical or even psychological factors. This has been said in enough places and occasions to astonish any seasoned conservationist. What is most surprising is the wide gap that still remains between accepting the previous proposition and really bringing it into our daily practice. We repeat this and similar phrases, nodding sympathetically when someone proclaims these kind of statements in each congress or professional meeting and, afterwards, it seems like we almost forget about it. It sounds like a concept that it is always nice to say, but we don't really need to turn it into actual actions.

One might even find a certain contradiction in the title of this book, which calls for an interdisciplinary approach to *ex situ* conservation and then invests most of its space discussing biological aspects focused on husbandry, genetic management, veterinary aspects and reproductive physiology. Is this really a multidisciplinary approach to *ex situ* conservation? I have no doubt about it. Does the width and detail of subjects included in the book adequately represent the challenges that will determine the final success or any recovery programme? Can we face *ex situ* conservation armed with this powerful multidisciplinary biological tool-kit? Would it be enough to bring species from the brink of extinction? I'm afraid not, and I would assume that many readers would agree with me. Then, why do we keep acting, meeting and publishing like if it was so?

I believe that the answer to this question does not lie in a deliberate effort to ignore pressing and uncomfortable non biological issues, but in our professional training. Through several years of reading books, attending meetings and workshops, we have been taught –in a very indirect subtle way, never explicitly– that conservation is mostly a biological challenge. When a certain group of subjects are repeatedly taught, discussed and written, they become the *only subjects that exist*. Such process is best described through what the economist and political scientist Herbet Simon (1983) called *bounded rationality:* the ability of the human mind to perceive and comprehend our environment through certain filters and approaches that allow us to selectively reject and ignore facts and views that are alien to our personality and education. Thus, it looks like we, conservationists, refuse to explicitly and systematically incorporate most social issues in our professional algorithms. This rejection is carried on even if we hear and read about the importance of such issues or while we might be actually dealing with them most of our time.

I think of my present professional situation: I must coordinate two *ex situ* conservation programmes for locally

endangered mammals in Argentina: one for the giant anteater and the other for the pampas deer. My original training is that of a zoologist. However, I spend around 80% of my time managing these programmes on social tasks: negotiating with government agents for animal donations; convincing other colleagues and institutions that they should join the processes or, at least, not try to block them; designing collaborative recovery plans with other stakeholders that would have a strong scientific, political and social support; talking to land-owners, forestry and agricultural businessmen to convince them that destroying critical habitat for those species should be part of their concerns or, at least, interests. Very seldom do I carry out some deer census on the field or supervise the capture, handling and transport of anteaters; these being the few clearly biological moments of my work.

It is clear to me that my biological-scientific training has been –and still is– extremely useful to guide my decisions and to help me convince other stakeholders. But it is also true that most of the time I see myself navigating through and trying to manage problems that are essentially non biological and will eventually determine if we achieve our conservation goals. And I do not see myself as an exception among professionals managing *ex situ* conservation programmes.

As an example, the Captive Breeding Programme for the Iberian lynx was blocked for years by interpersonal and interinstitutional conflict. As a result of such conflict, a measurable biological result was obtained: no Iberian lynx were born in captivity. Only when this history of destructive conflict was properly managed through the establishment of a consensus policy and a widely respected captive breeding team, we started witnessing the history of biological success so well described in this book. The lesson is simple: social and political problems can be behind the final failure or, at least, significant delay of many recovery programmes.

Hence, my purpose with this chapter is to join my voice to many others (Clark et al., 1994; Stephens and Maxwell, 1996; Clark, 1997; Clark and Wallace, 1998; Wallace et al., 2002, Groom et al., 2006; Robinson, 2006) to highlight one more time the key importance of social issues on any conservation programme, this being *in situ* or *ex situ*. To do so, I'll present some themes and recommendations that might guide professionals involved in these programmes. Whenever possible, and in order to fit the chapter within the spirit of this book, I will use examples from the Iberian lynx conservation process, of which I have been an external but passionate witness for more than 10 years.

I would like to send a simple message through this chapter. To specialists with a background in natural sciences who are involved in *ex situ*/*in situ* conservation programmes: be aware of your conceptual and academic biases –your bounded rationality– and be sensitive to the need for calling social scientists and professionals to bring their knowledge and expertise into the conservation challenge. To conservation professionals involved in actual management of *ex situ* and *in situ* populations: open your mind to a wide transdisciplinary understanding of the challenge at hand and try to set up interdisciplinary teams that can comprehend and handle it in its myriad of biological and social aspects.

Endangered species recovery as a complex social endeavour

Figure 1 presents groups of factors that determine the final success or failure of *ex situ*/*in situ* conservation programmes. At the end, success will depend of the final balance between reproduction and mortality. These two processes are directly influenced by the specie's own biology and some proximate biological threats affecting it, both in a potential reintroduction site as well as in captivity. Most of these factors have been discussed throughout this book. But reality tends to be more complex. There are social factors that affect and are also affected by the previous biological issues and wield an enormous effect on the recovery or extinction of an endangered species or population.

Some biological traits determine how society responds towards a certain species. Thus, large carnivores, like wolves, big cats or bears, tend to elicit passionate stands in favor or against their conservation, while many insects, fishes or plants receive a lukewarm response from public opinion (Kellert, 1997). On the other hand, the arrangement and interplay of stakeholders who are interested, affected or opposed to the conservation programme can affect its overall economical, political or legal support. Conservation programmes do not exist in a social vacuum. They always compete with other social interests for public support, these having to do with health, education, trade, entertainment or cultural issues, to name a few. As a result of this, the whole programme can flourish within its social context, get gridlocked in the middle of rampant conflict or dwindle from general public indifference.

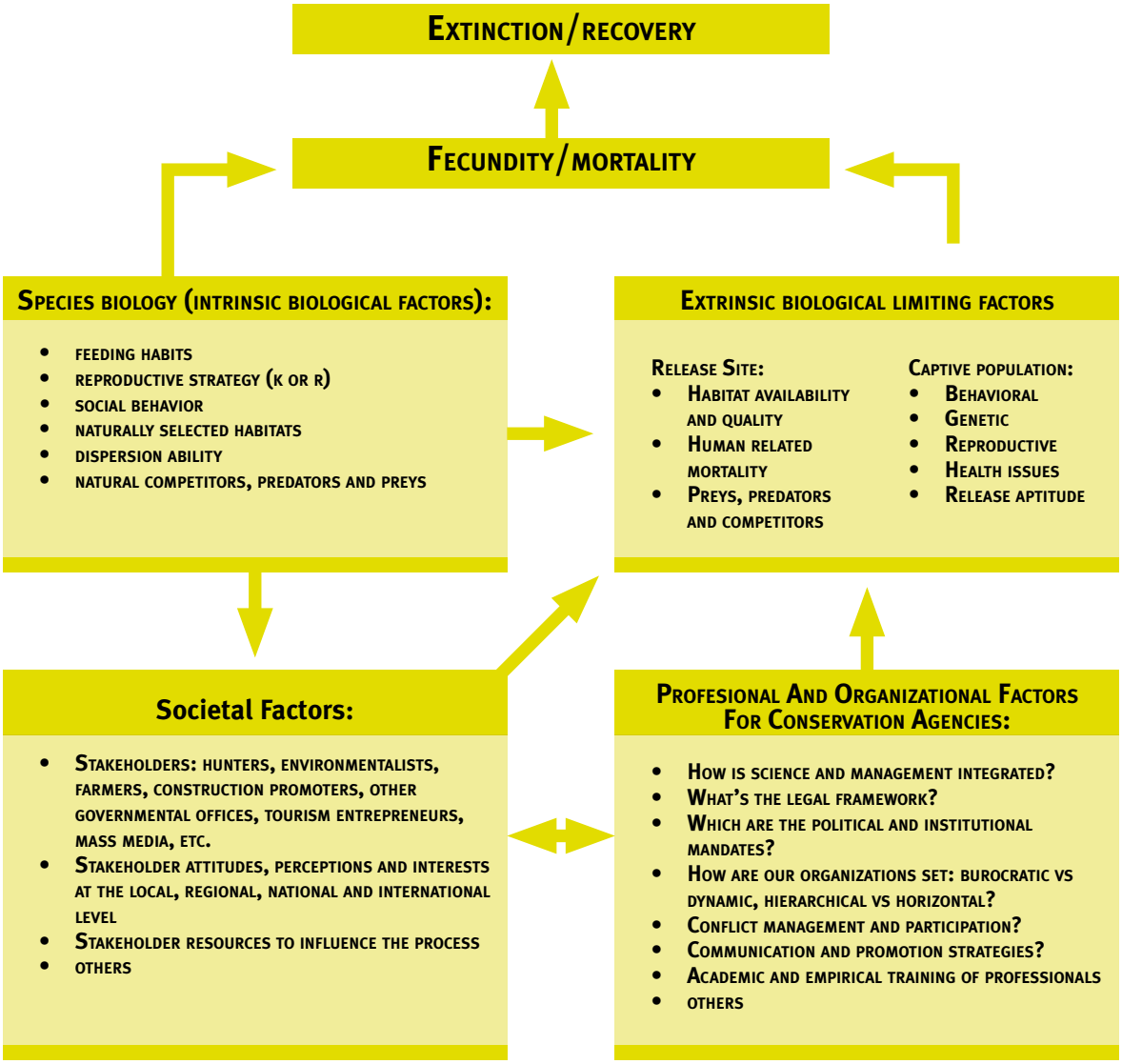

Figure 1. Factors affecting population recovery in *ex situ*/*in situ* conservation programmes.

Figura 1. Factores que afectan a la recuperación de una población en programas de conservación *ex situ* e *in situ*.

At the same time, while external social actors can have a key effect on the conservation programme, the way we, as conservationists, interact with other people and organizations involved in the same pursuit –allegedly to save the species from extinction– will have significant effect in the Programme's and, ultimately, the specie's fate. These interactions can be expressed in psychological, scientific, economic, communicational or organizational terms. It is no small paradox that some of the worst and most destructive conflicts blocking and threatening conservation programmes happen amongst conservationists; the previous example about the Iberian Lynx Captive Breeding Programme being a good example of this point.

As an example of social complexity surrounding a recovery programme we could check the stakeholders involved in the Iberian lynx reintroduction programme lead by the Andalusian Environmental Agency (Simón et al., this book). This institution holds the legal mandate and authority to conserve lynxes within its territory, and it can muster significant technical, financial and political resources to this task. The European Union stands out as an essential funding agency of such programme, which bestows a significant power to influence, if not veto, the whole process.

There are also two other agencies or ministries of the Andalusian government –Public Infrastructures and Agriculture– with less legal authority on the specie's conservation and, arguably, less interest on it, but much more clout over the general political process for the whole region. Other groups should be added to this list: the Spanish Central Government, represented by the Ministry of Rural, Marine and Natural Environment, is funding some components of the Programme and the neighboring government of Extremadura is an official partner of the Programme. Meanwhile, the government of Portugal and other regional governments in Spain have expressed their interest to gain access to the "Andalusian" lynxes to start their own *ex situ* programmes (Sarmento et al., this book; Vargas et al., this book).

But this is not all. The Programme also includes as official partners four environmental NGOs and three hunting associations, each with different access to public institutions and political centers. Around them there are several scientific advisors influencing the process, like the internationally renowned Doñana's Biological Station (CSIC) and the IUCN Cat Specialist Group, plus the always-vigilant gaze of the public opinion and the mass media. Any of these groups, by themselves or in alliance with others, has enough clout to promote, deter or divert major conservation actions and, eventually, the whole reintroduction programme. Each of these institutions and the many individual actors working for and within them bring into the overall conservation process a complex set of beliefs, demands, expectations, attitudes and approaches; many of which point towards interpersonal or interinstitutional conflict. Could anyone doubt that we are talking about a highly complex social endeavor?

Within this framework, it becomes especially relevant to analyze the social context surrounding an *ex situ*/*in situ* conservation programme. This implies identifying and understanding individuals and institutions whose very distinct interests are involved or affected by such programmes, and who can mobilize resources in order to arrive to results that favor those interests. Which are these interests? Following Lasswell (1971) we can propose that both individuals and groups are always looking to augment their share of the eight following basic "values": respect, rectitude, power, enlightenment, wealth, well-being, skill and affection. The key issue is that these values are not equally shared and sought by each person and institution. Even though we often assume that "we all look for the same things", this is not usually the case. For example, in the Iberian lynx reintroduction programme some institutions typically treasure and deploy power (i.e., Andalusian Environmental Agency), while others use wealth (i.e., European Union), enlightenment (i.e., Doñana Biological Station) or respect (IUCN Cat Specialist Group) as leverage. Even within these general groups there are interpersonal struggles, alliances and conflicts directed to trade and obtain any of the eight basic values. The startling fact is that many destructive conflicts are caused by people and institutions that claim the conservation of species as their main goal. Once we start seeing who gets or wants to get what from whom, we will be able to understand these conflicts and manage the social play of conservation in a much more efficient way. Achieving this does not require as much of a scientific-quantitative analysis of social process but a systematic and alert predisposition to study and understand human behavior. Any open-minded conservation professional armed with enough curiosity and patience should be able to achieve this.

Conflict as a potentially destructive or creative force

Throughout the previous paragraphs the term conflict has been used in several occasions. Conflict can be defined as the energy created by individuals and groups when they try to satisfy interests and objectives perceived as incompatible. Thus, conflict occurs when two or more players disagree over the distribution of material or symbolic values all of them related to the eight basic values described above, and start acting based on these perceived incompatibilities. Hence, convergence of multiple individuals and stakeholder groups with unique expectations, demands and identifications make conflict an inevitable ingredient of any conservation process receiving significant public attention.

The key issue is that, depending on how we manage any public conflict, it can either promote or harm actual conservation. People are most familiar with the negative aspects of conflict, which explains why many tend to avoid acknowledging its mere existence. The main problem with this approach is that it actually prevents us from seeing and promoting many positive aspects related to these situations. Thus, a conflict that is managed creatively tends to advance learning, team spirit, constant self-reflection, organizational adaptation and improvement. In 1999, after years of destructive conflict and interinstitutional gridlock surrounding captive breeding of Iberian lynxes, the Spanish Ministry of Environment called all relevant stakeholders to attend a participatory planning workshop in Madrid (see Vargas and Heredia, 2001). The explicit goal of such meeting was to agree on a National Captive Breeding Plan for the species and establish the basis for the Conservation

Figure 2. Reintroduced juvenile giant anteater in the Iberá region, Argentina.

Figura 2. Oso hormiguero gigante reintroducido en la región de Iberá, Argentina.

Figure 3. Building trust: biologist y gaucho talking about anteater reintroduction in Iberá.

Figura 3. Construyendo confianza: biólogo y gaucho hablando sobre la reintroducción del oso hormiguero gigante en Iberá.

Breeding Programme. The implicit goal, even if not evident to all attendants, was to try to manage destructive conflict in a more effective manner. To this purpose, an external and respected facilitator was hired, who used a collaborative decision making approach to create consensus from existent destructive dissension. In retrospect, one can identify that meeting as a turning point in the Iberian lynx conservation history and an excellent example of conflict and dissent used as a base from which to seek and build a more accepted public policy expressed through the resultant Captive Breeding Action Plan. In this line of thought, Lee (1993) identified bounded conflict as a major force for adaptation and improvement in conservation and other environmental processes in democratic societies.

Which specific actions can be pursued to advance creative conflict? First, we can follow the previous example with the Iberian lynx: call a professional with experience in conflict management. In another example, Johnson (2000) describes how, after many years of unproductive conflict between government biologists and landowners involved in the Alala or Hawaian crown recovery, they decided to hire a family therapist to work in relationship-building. This author describes how this unusual decision served to improve the way both groups communicated and worked together. It must be said that such progress did not suffice to avoid final extinction of this bird in the wild a few years later (Walters, 2006).

Second, it is important to turn possible competition into collaboration. When we started a reintroduction programme for the giant anteater in Northeastern Argentina (Figure 2) we soon found out that there was an Argentinean zoo that was already announcing a conservation project for the same species. This project was coordinated by a veterinarian experienced in zoo management, while we were field biologists trained in wildlife management. Zoos do not benefit from wide credibility in the Argentinean conservation community and many people tend to criticize them at ease. They were putting anteaters into a zoo, while we wanted to reintroduce animals in the wild. The setting was ripe for competitive and destructive conflict based on typically opposing world-views: biologists vs. veterinarians, wildlife managers vs. zoo people, *in situ* vs. *ex situ* conservation. Our decision was to turn this potential conflict into collaboration (Figure 3). Open, frank and respectful talks were initiated aimed to look for common ground. As a result of these, and in spite of remaining important differences and external pressures against collaboration, trust was built and both programmes have agreed to work together in the reintroduction of two captive anteaters previously included in the zoo project.

Third, another way to prevent and manage unproductive conflict is to build trust and collaboration through sharing non-distributive resources. When looking at the list of eight basic values sought by people, it might be

noted that some of these values like power, wealth and, somehow, rectitude tend to show a distributive nature. This means that whatever you give of these values you tend to loose it for yourself. When a governmental agency delegates authority to another institution it tends to loose its own power on this matter. A similar fact happens with money. One could even say that when one admits that a moral rival might be right (i.e., giving her the value of rectitude), at the same time one could be debilitating one's own moral position. Here is the foundation of competitive and destructive conflict: "I cannot help the other, because whatever I give her I end up loosing it for myself". Under this light we are condemned to rivalry entangled within a mesh of interdependent relationships.

The trick is that our cultural tradition is too fixed on distributive interpersonal exchanges. When looking to the other values sought by people, including potential rivals or allies, we notice that they do not have a distributive nature. Any person can share respect, skills, information and affection with another without finding its share of them diminished. On the contrary, the fact that I offer respect to another person or institution –even if major disagreements interpose between us may actually increase my own respect. Here is a pathway to building trust and creative collaboration: one can freely share these values with actual or potential rivals and turn them into allies or, at least, into respectful and civilized neighbors.

Managing organizational issues

Most issues described up to this point deal with the way we relate with other conservationists and society in general. But there are also issues related to the way we organize ourselves to achieve our goals as conservationists that are critical to the success or failure of such enterprise (see the box on the bottom right of Figure 1). We could assume that most organizational shortcomings and failures stem from three general problems: 1) lack of a clear and shared vision and direction; 2) lack of action, also known as the *implementation gap*, and 3) inaccurate assumptions and inadequate knowledge.

Many recovery conservation programmes are built without a clear and shared idea of their ultimate goals and the approaches and methods needed to achieve them. In some cases an *ex situ* conservation programme is proposed when there is no clear evidence of how it would benefit the target population or species. Animals are bred and/or released without a clearly identified conservation need for these actions. In other cases, different actors and organizations hold divergent or antagonistic views of the challenge at hand, its desired result and the means to achieve it. Clark (1997) uses the conservation story of the black-footed ferret captive breeding and reintroduction programme as an example of this interinstitutional lack of agreement.

Open, frequent and effective communication amongst all relevant stakeholders serves as a general solution for this major problem. This should include arranging and managing regular collaborative planning instances that can help to: 1) establish a clear and shared vision of the common task; 2) call for multiple resources for *ex situ*/*in situ* conservation actions; 3) establish effective organizational structures, and 4) set the bases for continuous learning through monitoring, evaluation and widespread information exchange.

Plans can be agreed, and a clear and shared vision can be built, but that does not assure proper implementation of effective actions directed to change the status of our target population. Clark (1997) described this organizational problem as the implementation gap: actions may be identified and agreed upon but they are not actually carried on. A classical solution proposed for these situations is to call for increased funding. Proper funding is certainly a key issue but it does not assure adequate implementation, unless there is an organizational structure that is designed and adapted for its effective and efficient management. Several organizational arrangements can improve actual performance.

First, it is important to find a right balance between high control and low executive levels. In any organization there are high decision levels (i.e., chiefs, directors or political appointees) that are in charge of outlining general policies and monitoring their compliance. Below them there are usually teams or individual professionals who are in charge of implementing these policies. The former offer a sense of general direction and tend to insert any programme within a larger policy frame, while the latter take care of on-site executive matters. Implementation gaps tend to appear when high levels of control override executive groups thwarting their timely and efficient functioning, this being a typical result of bureaucratic organizations. Clark et al. (1994) described and analysed several conservation processes where this happened.

Second, in order to avoid implementation gaps in recovery programmes it is key to identify, train and empower programme leaders and active teams who are in charge of executive matters. What kind of leader do we want to have in such position? It could be summarized to: someone who wakes up in the morning reflecting about how to reestablish the species in accordance to other groups and people. What kind of person we do not want in such position? Someone who wakes up without reflecting about how to recover the species, who promotes a business as usual attitude and who is just thinking about how to keep control of the process or wanting to save the population excluding other interested parties. In order to promote effective implementation, conservation teams would benefit from showing the following traits: motivated, professional, empowered, focused on the task, ready to learn, interdisciplinary and open-minded.

Third, conservation institutions should be aware of the need to prevent and avoid *goal displacement*. Goal displacement occurs when a person or organization starts acting in ways that harm their explicit goal but benefit a second and often unexpressed purpose, typically related to programme control, career advancement or position strengthening. The problem is widespread, and also very human, because we all want other things besides avoiding some specie's extinction. Examples abound: Clark (1997) and Reading and Miller (1994) use the concept to describe actions taken by the Wyoming Department of Game and Fish in order to control the black-footed ferret programme. Lieberknecht (2000) identifies "goal substitution" as the "the root of the policy problem" in the conservation of the Barton Springs Salamander in Texas. The author proposes that "participants, such as the federal government (...), the state government (...), and environmentalist groups (...), have substituted the purpose of power for their stated goal of salamander conservation". And, Naves (2005), while analysing brown bear conservation in Asturias, Spain, described decisions taken by the relevant governmental agency, which favoured programme control over implementation of needed research and management actions.

Programme evaluation: organizational learning for *ex situ* conservation

Conservation is a complex task inserted in a context of scientific, political and social uncertainty. There is a need to act early to prevent species extinction, even if we have not discerned all relevant facts. Still, when we are able to get a clear picture of what is happening and what needs to be done, the context becomes too dynamic and tends to change in fast and unpredicted ways by the time we start acting. Here lies a major organizational challenge: the need to take decisions and act in an environment of uncertainty and change, while trying to avoid that these decisions and subsequent actions are based on inadequate knowledge and wrong assumptions. In this regard, several authors have proposed adaptive management as the paradigm that should guide decision-making in conservation programmes and other complex natural resource challenges (Lee, 1993; Salafsky et al., 2001). Within this framework, programme evaluation takes a leading role.

Programme evaluation implies the continuous questioning and reflection on our assumptions, objectives and methods and, sometimes, even our final goals. A permanent questioning when managing a conservation programme should be: what are we assuming or doing that is wrong or, at least, clearly improbable , perhaps ineffective or even potentially harmful? Programme evaluation helps us frame and answer that question. Evaluation could be either internal or external and formal or informal (see Backhouse et al., 1996) (Figure 4). Any programme can benefit from a combination of these complementary approaches. Informal internal evaluation implies creating a working environment where all programme participants can openly share thoughts, worries and proposals related to the conservation task. It also involves encouraging reflection and constructive criticism while searching for and creating spaces and moments when most programme members can meet face to face.

External informal evaluation implies bringing frequent "fresh air" into the Programme. The key word is transparency: make your objectives, methods and protocols public so they can be reviewed and criticized by all relevant experts and, whenever possible and sensible, all possible stakeholders. Open your breeding and quarantine facilities, and show your release and monitoring methods to national and foreign experts. This will encourage a collective learning process that goes beyond the Programme's staff and turns conservation into a matter of truly public interest.

Internal formal evaluation means designing plans and strategies in order to monitor programme performance at several levels (i.e., goals, objectives and activities; see Margoluis and Salafsky, 1998). Such evaluation requires developing measurable goals and objectives, establishing performance indicators for each one of these

	Informal	Formal
Internal	Regular (weekly, monthly) coordination and evaluation meetings among team members	Regular (bi-annual, annual) evaluation and planning among team members and collaborators
External	*Ad hoc* evaluation, taking advantage of visits from experts in the subject	Programme evaluation by external experts (recommended every 5 years)

Figure 4. Types of evaluation in conservation programmes.

Figure 4. Tipos de evaluación en programas de conservación.

and, most important, assigning time and resources within the programme for systematic monitoring of their compliance. It also means taking programme-monitoring results seriously and being ready to change based on these findings.

Finally, external formal evaluation implies calling for an external agent to carry out a thorough review of your programmes' performance. Backhouse et al. (1994) describe the story and results of one such evaluation for the Eastern barred bandicoot recovery programme. This Australian marsupial was protected since the 1970s and a conservation programme was initiated in the 80s. By 1988 the species had lost 98% of its original distribution and abundance, with only 190 remaining animals alive. At that time it was obvious that the recovery programme was not working properly and a major formal evaluation was called for, which included foreign evaluators from the United States. The evaluation cited major weaknesses related to the Programmes' organization and operation: 1) causes of decline were poorly known; 2) there was an underestimation of the situation's urgency and a business as usual attitude towards the whole programme; 3) inadequate planning was used where clear goals, time frames and responsibilities were absent; 4) there was lack of good information about relevant social and organizational aspects; 5) absence of systematic monitoring and evaluation procedures directed to learning and programme improvements; 6) lack of effective leadership, and 7) poor communication among programme participants. As a result of this evaluation, there was a major programme reorganization, which was very much focused on improving programmatic and organizational aspects. Greatly as a result of this evaluation and reorganization process, by the end of the 1990s there were more than 1000 bandicoots established at six reintroduction sites, plus the original population and a captive breeding programme.

Each one of these evaluation approaches has its own advantages and caveats. Discussing them goes beyond the space and scope of this chapter. Nevertheless it must be highlighted that any recovery programme would benefit from using all four approaches at different times and under different circumstances throughout its history. In an environment where programme organization and performance can make the difference between a species survival or extinction it is peremptory to invest time, thoughts and resources in making constant assessments and improvements of our own actions.

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Epilogue

EPÍLOGO

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Pegado a la tierra, aplastado entre las ramas, desolado por el cansancio y quizás también por el miedo, el lince dejó pasar la noche sin moverse, tratando de dominar el hambre. De pronto cerró los ojos y se quedó dormido; como una piedra cae en el agua de un pozo oscuro, así le vino el sueño. Por los movimientos de la boca -que repetían la perfecta dentellada mortal en el cuello-, parecía que el lince estaba soñando. Soñaba con un inmenso espacio cubierto de encinares y repleto de conejos..

El lince, el cazador y los sueños
Julio Manuel de la Rosa

El lince ibérico de ayer a mañana

Escribió Antonio Machado: "El hoy es malo, pero el mañana... es mío/ Y es hoy aquel mañana de ayer". No lo decía el poeta en un contexto optimista, pero sus versos, a nosotros, nos permiten serlo. Hace apenas un par de lustros constatábamos la nefasta situación del lince ibérico. Cada día empeoraba un poquito. Paradójicamente, como a veces se atribuye a la política, para el lince también fue realidad aquello de "cuanto peor, mejor". Resultó necesario tocar fondo para empezar a alzarse, pero entre todos decidimos hacerlo y nos estamos levantando. Nuestro hoy no es peor, por tanto, que el mañana soñado ayer, y el programa de conservación *ex situ* tiene mucho que ver en ello.

Bastantes años atrás, en una reunión del Grupo de Trabajo del Lince (injustamente olvidado y, en la práctica, lamentablemente disuelto) que convocaba y presidía el Ministerio de Medio Ambiente, nos dimos cuenta de que, para evitar la inminente extinción del lince ibérico (y, más aún, para posibilitar su recuperación), era insuficiente reiterar las medidas genéricas habituales (i.e. respetar el hábitat, evitar la mortalidad reduciendo el furtivismo, incrementar la abundancia de conejos, etc.). Había que plantearse actuaciones activas, y urgentes, en espacios concretos. Necesitábamos para ello abandonar el oscurantismo y hacer la luz, pese a sus evidentes riesgos. En primer lugar, había que saber, y había que decir, donde había linces, de forma que pudieran optimizarse los esfuerzos y las inversiones. Y luego, donde se decidiera, había que tomar medidas drásticas, negociando con propietarios, repoblando con conejos, limitando las infraestructuras, erradicando lazos y cepos, etc. Y la sociedad debía saberlo. Pero todo eso aún era poco para lo que pretendíamos.

Recuerdo haber hablado en aquella época de la necesidad de medidas urgentes estructuradas como un taburete. Mencionaba tres patas y un asiento, una superficie horizontal uniéndolas. La primera y más urgente de las patas era trabajar para detener la hemorragia, para frenar el declive poblacional; inútil parecía diseñar el futuro de los linces si, allí donde todavía vivían, no se les garantizaba el presente. La segunda pata incluía confirmar la presencia de la especie en áreas propicias pero tal vez poco muestreadas, o donde pudieran quedar muy pocos ejemplares, así como garantizar, no sólo en esas áreas, la conservación de hábitat suficiente para permitir la existencia en un futuro próximo de otras poblaciones, además de las conocidas. La tercera pata eran las medidas "artificiales" tendentes a crear o, en su caso, a consolidar, esos nuevos núcleos poblacionales, desde la translocación de ejemplares silvestres de unas zonas a otras, a la producción de animales en cautividad para su posterior liberación. Recuerdo haber escrito a ese respecto: "Hay que aprender a criar linces en cautividad, como último recurso, y existe ya

un buen plan sobre el modo de llevarlo a cabo. Alguien tiene que tomar el toro por los cuernos y decidirse a hacerlo, con todas sus consecuencias". Por fin, el asiento debía estar formado por las medidas horizontales imprescindibles, como la educación y la sensibilización.

Hemos avanzado mucho, aunque siempre sepa a poco. La mayor parte de esas propuestas están recogidas en la recientemente aprobaba Estrategia Nacional para la recuperación del lince, a la que parece sumarse de buena gana Portugal (convendría, por cierto, oficializar una estrategia ibérica). La conservación de las poblaciones conocidas ha sido abordada con éxito en Sierra Morena y algo menos en Doñana por la Junta de Andalucía, con enorme esfuerzo gracias al apoyo de un proyecto LIFE. Y en su día la Junta de Andalucía y el Ministerio de Medio Ambiente cogieron, efectivamente, el toro por los cuernos y el proyecto de conservación *ex situ*, como refiere este libro, es una brillante realidad. Pero lo que quiero enfatizar en el contexto del libro es que, contra todo pronóstico, la tabla que sujeta las patas de nuestro taburete, el engrudo que une a unos actores con otros, unas actuaciones con otras, el lubricante que suaviza y aminora las tensiones personales e institucionales, ha resultado ser la conservación *ex situ*. Lejos de limitarse a proporcionarnos los ejemplares precisos para los ensayos de recolonización de áreas perdidas, más allá de constituir ese salvavidas, o colchón protector, que debía permitirnos trabajar con más tranquilidad justo en el borde del abismo, el programa de cría en cautividad, con su directora al frente, se ha mostrado como el más enérgico y transparente propulsor de la conservación del lince, también *in situ*.

Es digno de aplauso (y unánimemente aplaudido), pero creo sinceramente que es una carga excesiva para el equipo de conservación *ex situ* y las personas que lo dirigen. Lo han hecho ellos porque era necesario y nadie lo hacía, porque no sabíamos o simplemente porque no podíamos. Gracias al éxito de la cría en cautividad y, sobre todo, gracias a las complejas redes (políticas, administrativas, científicas, informativas, humanas…), nacionales e internacionales, tejidas alrededor del programa, la disposición psicológica hacia la conservación del lince ibérico ha cambiado 180º. Hasta hace muy poco nos reuníamos con ánimo desesperado, con el único objetivo de evitar la extinción de la especie, que se antojaba casi inevitable. Desde hace muy poco tiempo, casi sin darnos cuenta, hemos pasado a discutir en las reuniones cómo vamos a conseguir que el lince vuelva a Portugal, y enseguida a las Comunidades Autónomas españolas que lo han perdido hace poco. Está de moda el término "Podemos", pues lo utilizó Obama y ganó por goleada. Con los altibajos inevitables en un mundo y un sistema económico que no invitan al optimismo, al menos en lo que se refiere a la conservación de la naturaleza, en el caso del lince hemos pasado a creer en nuestro propio trabajo.

Pero decía que los responsables del programa de conservación *ex situ* no pueden seguir haciéndolo todo. Hay que adoptar su espíritu de trabajo, su voluntad de diálogo y, si posible fuera, incluso sus actitudes personales, pero deben sustituirlos los investigadores en los laboratorios, las Comunidades Autónomas (y Portugal) en el campo, y el Ministerio de Medio Ambiente, Rural y Marino en la coordinación que le corresponde. Mi sensación en estos momentos es que el armazón que sujeta a la recuperación del lince ibérico lo componen, básicamente, unas pocas personas concretas. Son cañas fuertes, pero pueden quebrarse, y si no se reparte el trabajo acabarán quebrándose algún día. Necesitamos una estructura administrativa fuerte, una coordinación eficiente, un diálogo permanente, transmitir a la sociedad una información clara… A fuer de sincero, creo que vienen tiempos buenos para el lince ibérico, pienso que va a ir a mejor. Pero van a ser, también, tiempos difíciles. Inevitablemente, habrá cosas que nos saldrán mal y otras que, aun saliendo bien, parecerán negativas a ojos de la gente (e.g. muchos linces morirán antes de que otros puedan establecerse de forma permanente en nuevas tierras). Esas dificultades deben pillarnos unidos y con una estructura fuerte, capaz de aguantar críticas, eventuales desánimos e incluso abandonos.

Hoy es el mañana de ayer, y siempre será así. Otro poeta, Ángel González, ha escrito: "Te llaman porvenir/ porque no vienes nunca", y enseguida: "¡Mañana!/ Y mañana será otro día tranquilo/ un día como hoy, jueves

o martes,/ cualquier cosa y no eso/ que esperamos aún, todavía, siempre". Efectivamente, nos cansaremos de esperar ese futuro feliz que anhelamos, el mañana de una Península Ibérica poblada por linces en gran parte de su extensión, sin mayores problemas. Nunca ha ocurrido y seguramente nunca ocurrirá. Si alguna vez hubo muchos linces, se cazaron por su piel y su carne, cuando hubo muchos conejos, se colocaron cepos y lazos que mataron a los linces, en las épocas en que el monte se limpiaba estaba demasiado limpio y usado... Conservar al lince ibérico será complicado siempre y exigirá trabajar duro. Pero hemos de hacerlo porque, aunque el hoy no sea tan malo como hace diez años, el incierto mañana sigue siendo nuestro.

Miguel Delibes de Castro

The Iberian lynx from yesterday to tomorrow

As the great Spanish poet Antonio Machado wrote, "Today is bad, but tomorrow… is mine/ And today is the tomorrow of that yesterday." Although the context in which he wrote this was not optimistic, his verses give us reasons for hope. We became aware of the disastrous situation of the Iberian lynx only a decade ago. It was getting a little worse every day. Paradoxically, as it sometimes happens in politics, only after hitting rock bottom did we start to go up again, but we decided to do it together and we are rising. Therefore, our today is not worse than yesterday's dream of tomorrow, and the *ex situ* conservation programme has a lot to do with this.

Quite a few years ago, the Spanish Ministry of the Environment organised and chaired a meeting of the Working Group on the Iberian lynx, which has been unjustly forgotten and was unfortunately terminated. On that occasion, we realised that, to avoid the imminent extinction of the Iberian lynx (and, what is more, for its recovery to be possible), it was not enough to reiterate the usual generic measures (i.e., conserve the species' habitat, avoid mortality by reducing poaching, increase rabbit abundance, and the like). Active and urgent measures were needed in specific areas. To achieve this, we had to come out of the darkness and shed some light on these issues, in spite of the obvious risks involved. First, we needed to know and say where the lynx was present to optimise efforts and resources. Also, strict measures had to be taken in targeted areas, negotiating with landowners, restocking rabbit populations, limiting infrastructures, eradicating traps and snares, and so on. And society had to hear about it. But this was still not enough to achieve our goal.

Back then, I remember saying that we needed urgent measures with the structure of a stool. I mentioned three legs and a seat, a horizontal surface bringing the legs together. The first and most urgent of the legs was to try to stop the haemorrhage, to slow down the population decline; it seemed useless to design the future of the lynx if we did not guarantee its presence in areas where it still occurred. The second leg involved confirming the presence of the species in favourable areas where little sampling had been done, or where very few individuals might still be left; we should also guarantee the conservation of enough habitat in those areas and others for other lynx populations apart from the known ones to be able to exist in the near future. The third leg referred to "artificial" measures to create or consolidate new populations; such measures ranged from the translocation of wild individuals to other areas to captive breeding of animals for later release. I wrote about this at the time, saying "We must learn to breed lynx in captivity as a last resort, and there is already a good plan on how to do it. Someone has to grab the

bull by the horns and do it, with all its consequences." Finally, the seat should be formed by the essential cross-cutting measures such as education and awareness-raising.

We have made great progress, although it always seems too little. Most of these proposals have been included in the recently adopted Spanish National Strategy for the Recovery of the Iberian Lynx, which Portugal seems to willingly adhere to (it would be good to set up an official Iberian Strategy, by the way). The conservation of the known populations of Iberian lynx has been dealt with successfully in Sierra Morena and somewhat less so in Doñana by the Regional Government of Andalucía, in a huge effort thanks to the support of a LIFE project. Indeed, the Regional Government of Andalucía and the Spanish Ministry of the Environment grabbed the bull by the horns at that point and the *ex situ* conservation programme that this book is about is now a brilliant reality. However, in the context of this book I wish to highlight that, against all odds, the board that holds the legs of our stool together, the glue that joins the various players and actions, the oil that eases and reduces personal and institutional tensions has turned out to be *ex situ* conservation. The captive breeding programme has done much more than just provide the specimens needed to try to recolonise lost areas and be a safety net to allow us to work with greater confidence on the edge of the abyss. Beyond all this, the captive breeding program, headed by its director, has proven to be the most energetic and transparent driving force of lynx conservation *in situ* as well.

This is worthy of praise (and unanimously praised), but I honestly consider that it is an excessive burden for the *ex situ* conservation team and the people who head it. They did it because it was necessary and nobody was doing it, because we did not know how to or we simply were not able to. Thanks to the success of captive breeding and especially thanks to the complex national and international networks (political, administrative, scientific, information, human networks and more) woven around the programme, the psychological attitude towards the conservation of the Iberian lynx has radically changed. Until very recently, our meetings were held in a desperate mood, with the only objective of preventing the extinction of the species, which was seen as almost inevitable. Almost without noticing, we have recently started to discuss how to ensure that the lynx returns to Portugal and the Spanish regions where the species recently disappeared. The expression "Yes we can" has become popular after Obama used it and won by a landslide. With the inevitable ups and downs in a world and an economic system that do not inspire optimism, at least for nature conservation, in the case of the lynx we now believe in our own work.

Yet, I was saying that the people in charge of the *ex situ* conservation programme cannot continue to do everything. Their working spirit, their willingness for dialogue and, if possible, even their personal attitude should be adopted by others, but these people should be replaced by researchers in laboratories, the Spanish regions (and Portugal) in the field, and the Spanish Ministry of the Environment and Rural and Marine Affairs in the coordination work that suits it. My feeling today is that the structure upholding the recovery of the Iberian lynx is basically composed of just a few people. They are strong poles, but might break and will eventually break if work is not shared by others. We need a strong administrative structure, efficient coordination, permanent dialogue, and to convey clear information to society... To be honest, I think good times are coming for the Iberian lynx. I think the situation will improve, but times will also be difficult. Inevitably, we will sometimes fail; even when good results are obtained, people will sometimes see them as being negative (e.g., many lynx will have to die before others can permanently settle in new areas). When these difficulties happen, we must be united and have a strong structure that can withstand criticism, possible discouragement and even resignations.

Today is yesterday's tomorrow, and it will always be so. Another Spanish poet, Angel González, wrote "They call you the time to come because you never come," and "Tomorrow!/ And tomorrow will be another quiet day/ a

day like today, Thursday or Tuesday,/ anything but what we still, always wait for." Indeed, we will get tired of waiting for this happy future that we long for, the tomorrow of an Iberian Peninsula with lynx in most of its areas without any problems. It has never happened and most likely never will. If there were ever many lynx, they were hunted for their pelts and their meat; when there were many rabbits, traps and snares were placed to kill the lynx; when the woodland was cleaned it was too clean and used... Conserving the Iberian lynx will always be complicated and will require hard work. But we must do it because although today is not as bad as ten years ago, the uncertain tomorrow is still ours.

Miguel Delibes de Castro

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Esperamos que este libro sirva como herramienta de trabajo para conservar especies y como herramienta de ocio e inspiración para quienes desean disfrutar de las hermosas imágenes, versos y citas que acompañan a los textos. Nuestra intención es acercar al lector al lince ibérico combinando ciencia y arte. Como expresa el artista Joe Zammit-Lucia en su obra más reciente *"El arte puede ayudar a que las personas se involucren a través de sus emociones. Esto es vital porque si la gente no se implica emocionalmente en temas ambientales no tendremos ninguna posibilidad."* Con la ayuda de todos conseguiremos que el lince ibérico vuelva a ser una pieza funcional de su ecosistema, el monte mediterráneo. Como parte de este ecosistema, el lince es una especie clave ya que mantiene a raya a otros carnívoros, como los zorros y meloncillos, y paradójicamente, consigue de ese modo que donde viven linces haya más conejos, su presa principal. Además, es un símbolo del monte mediterráneo, un abanderado de la conservación en el mundo y también un paraguas que puede servir para conservar a muchas otras especies. Si logramos recuperar al lince, conseguiremos proteger una gran diversidad de plantas, animales, hongos y microorganismos que dependen de este rico ecosistema para su supervivencia. Invertir en el futuro del lince ibérico es, por tanto, invertir en la sostenibilidad de nuestro ecosistema más diverso y emblemático. Como recientemente apuntaba Miguel Delibes, *"No podemos dejar caer al lince. Los humanos necesitamos la naturaleza bien conservada para vivir. Defendiendo al lince defendemos la dignidad, las haciendas, e incluso la vida de millones de personas vivas o que vivirán".*

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We hope that this book will serve as a working tool for conserving species and as a tool for leisure and inspiration for those who want to enjoy the beautiful images, verses and quotes that complement the chapters. Our intention is to bring the reader closer to the Iberian lynx by combining science and art. As the artist Joe Zammit Lucia expresses it, *"Art can help engage people at an emotional level. That is vital because without emotional involvement in environmental issues we have no chance."* With everyone´s engagement we will be able to achieve that the Iberian lynx becomes again a functional piece of its ecosystem, the Mediterranean forest. As a part of this ecosystem, the lynx is a keystone species, since it controls the presence of other carnivores, such as foxes and mongooses and, paradoxically, where lynxes thrive so do rabbits, its main prey base. In addition, the lynx is a symbol of the Iberian Mediterranean forest, a conservation flagship for the world, and an umbrella that can help preserve many other species. If we manage to recover the Iberian lynx, we will manage to protect a great diversity of plants, animals, fungi, and microorganisms that depend on this rich ecosystem for survival. To invest in the future of the Iberian lynx is to invest in the sustainability of our most diverse and emblematic ecosystem. As Miguel Delibes recently conveyed, *"We cannot let the lynx fall. To survive, humans need a well-conserved nature. Defending the lynx we are defending the dignity, the homesteads, and even the lives of millions of people that live in the present or that will live in the future."*

Circles of Our Lives

Within the circles of our lives
we dance the circles of the years,
the circles of the seasons
within the circles of the years,
the cycles of the moon
within the circles of the seasons,
the circles of our reasons
within the cycles of the moon.
Again, again we come and go,
changed, changing. Hands
join, unjoin in love and fear,
grief and joy. The circles turn,
each giving into each, into all.
Only music keeps us here,
each by all the others held.
In the hold of hands and eyes
we turn in pairs, that joining
joining each to all again.
And then we turn aside, alone,
out of the sunlight gone
into the darker circles of return.

Wendell Berry

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Like the resource it seeks to protect, wildlife conservation must be dynamic, changing as conditions change, seeking always to become more effective.

Rachel Carson
(1907-1964)

La ciencia se compone de errores, que, a su vez, son los pasos hacia la verdad.

Julio Cortázar
(1914-1984)

No vayas a creer lo que te cuentan del mundo (ni siquiera esto que te estoy contando) ya te dije que el mundo es incontable.

Mario Benedetti
(1920-2009)

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