Instituto da Conservação da Natureza

The Iberian Lynx in Portugal

STATUS SURVEY AND CONSERVATION ACTION PLAN

ICN´ S LYNX MONITORING TEAM

February 2004

-THE IBERIAN LYNX IN PORTUGAL-
-Status Survey and Conservation Action Plan-

Project coordinator: Pedro Sarmento – Reserva Natural da Serra da Malcata – Rua António Ribeiro Sanches 6090 Penamacor Portugal – e-mail: rnsm.sarmentop@icn.pt

Project Staff:

Field Biologists:

Pedro Monterroso – Parque Natural do Guadiana. Rua Dr. Afonso Costa, 40 1ª Dt, 7750-352 Mértola. E-mail: monterroso_pedro@hotmail.com
Pedro Tarroso - Reserva Natural da Serra da Malcata – Rua António Ribeiro Sanches 6090 Penamacor Portugal – E-mail: ptg@clix.pt
Catarina Ferreira – Parque Natural do Sudoeste Alentejano e Costa Vicentina. Rua Serpa Pinto, 32, 7630-174 Odemira. E-mail: catferreira@net.sapo.pt
Nuno Negrões – Parque Nacional da Peneda-Gerês. Av. António Macedo, 4704-538 Braga. E-mail: nunonegroes@megamail.pt
Luís Castro – Instituto da Conservação da Natureza/Divisão de Habitats e ecossistemas – Rua Filipe Folque, n.º 46 1150-144 Lisboa.
Joana Cruz Reserva Natural da Serra da Malcata – Rua António Ribeiro Sanches 6090 Penamacor Portugal. E-mail: joana.cruz@sapo.pt
Bruno Pinto- Instituto da Conservação da Natureza/Divisão de Habitats e ecossistemas – Rua Filipe Folque, n.º 46 1150-144 Lisboa.
João Pargana – Parque Natural da Serra de S. Mamede. Rua General Conde de Avilez, 22 – 1º , 7300-185 Portalegre. E-mail. pnssm.parganaj@icn.pt

Field assistents:

José H. Fernandes, Francisco Campos, Nuno Cardoso, José Pires, António José Silva, Armando Dias, Luís Correia, Carlos Fradoca, Rui Vaz, António Domingos, Carlos Santos, Eduardo Silva, Paulo Tenreiro, Ana Cristina Cardoso, Carlos Franco, João Baptista, Maria da Conceição Conde, Ana Maria Cavaco, António Parente, Paula Duarte, Marco Paulo Saraiva, Manuel Dória, Pedro Rosa, Fernando Ildefonso, Pedro Portela, Paulo Cabrita, Ana Nunes, Joaquim Azevedo, Albino Palhares, José Manuel Ribeiro, João Pereira, Alexandre Ferreira, Isabel Mandim, Paulo Barros, António Barros, João Correia, Jacinto Diamantino, Filipe Moniz, Carlos Carrapato.

Report should be cited as: Sarmento, P., Cruz, J., Monterroso, P., Tarroso, P., Negrões, N. & Ferreira, C. (2004). The Iberian lynx in Portugal. Status survey and conservation action plan. Instituto da Conservação da Natureza (ICN).

On the cover: Iberian lynx “Esperanza” photographed in El Acebuche Reproduction Centre by Carlos Carrapato.

-TABLE OF CONTENTS-

-EXECUTIVE SUMMARY-

A team of biologists and field assistants conducted, between January 2002 and May 2003, a survey on the status of the Iberian lynx in Portugal. The survey was performed over previously identified lynx areas, during studies carried out in the 1970-s and 1990-s. The following objectives were established:

1- To design a baseline of status and distribution of the species for result comparison of subsequent surveys on a national scale;
2- To develop a simple and reliable method of collecting information to facilitate future surveys;
3- To analyse rabbit distribution and abundance within the lynx historical range;
4- To define potential areas for capturing founders for a captive breeding programme.

Intensive search for lynx scats, for DNA analysis, and camera trapping provided a basis for identifying potential lynx areas. Over 4200 km were covered during a global searching effort of 1975 man-hours. This effort resulted in the collection of 168 potential scats, that were submitted to genetic validation with no positive lynx amplifications. Camera trapping was applied in a total effort of 5647 camera days, in three lynx potential areas. No positive detections were achieved. At the same time, a study on wild rabbit distribution reveal that most historical nuclei do not support lynx viable populations. Although we can not confirm extinction, the scenario is highly pessimistic. The Iberian lynx is presently in the verge of extinction. Intensive rabbit regression and massive habitat destruction are identified as the main causes of decline in recent decades. In the Portuguese lynx historical range, we could only identify significant areas suitable for lynx in the South-eastern part of the country, particularly in the Andalusian border, where we lack on recent evidence of lynx presence.

Being aware of the considerable difficulties pointed above, the ICN 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.

This proposal describes guidance that retains future options, provides management consistent, offers necessary flexibility, in order to achieve the maximum goal of conserving the lynx in Portugal. Conservation measures have the goal of provide guiding lines for conservations agents in order to conduct actions that can positively affect lynx and/or to help avoid negative impacts through thoughtful planning of activities.

The proposal of Action Plan will be applied in all the areas located in the lynx historical distribution geographic area, that present suitable characteristics for the species presence or landscape features that can be optimise for lynx survival and that can be relevant for the species life-cycle, independently of their protection status. The goal of this plan is to apply pre-release strategic reintroduction activities to make possible, in a long-term, the reintroduction of Iberian lynx, in order to assure the viability of the species, as a fundamental element of Mediterranean ecosystems. For achieving this goal it will be necessary to establish a suitable connection between *ex-situ* and *in-situ* actions.

AKNOLEDGEMENTS

The authors of the report express their gratitude to Nicolás Guzmán (MIMAM/DGCN), Carlos D´Ávilla (Junta Autónoma de Extremadura), Pablo Pereira and Célia Sanchez (PN de Doñana) for their helpful support in all phases of the work.

1. INTRODUCTION

1.1 The species

The Iberian lynx (*Lynx pardinus*) is a cat species with an highly restricted geographic distribution, occurring only in Portugal and in Spain. Presently, is classified as the most endangered carnivore in Europe (Delibes *et al.*, 2000) and as the most endangered feline in the world (Nowell & Jackson, 1996), being recently listed by the UICN as critically endangered.

Identified, since the mid 1990-ies, as an independent taxonomic identity, at the species level, distinct from the Eurasian lynx (*Lynx lynx*) (Beltrán *et al.*, 1996), this species numbers have declined over the last century, and this decline was accelerated in the last 10 years (Guzmán *et al.*, 2002).

They were once distributed through much of Iberian Peninsula (Delibes, 1979). Now, however, they have been extirpated from most of their range - they are extinct in most Spanish autonomic regions (Guzmán *et al.*, 2002) and in a significant percentage of Portuguese territory. Today, Iberian lynx population numbers are between 150 and 200 animals distributed by two reproductive populations: Doñana and Cardeña-Andújar (Guzmán *et al.*, 2002).

The ultimate cause of Iberian lynx's decline has been a combination of persecution (Ferreras, *et al.*, 1992; Oreja, 1998), habitat loss and rabbit (*Oryctolagus cuniculus*) regression (Delibes *et al.*, 2000). As a result of this process, today lynxes persist only in areas with relatively low human population densities.

Although lynxes numbers have declined markedly, it is not too late to prevent their extinction. However, to conserve this species, we must concentrate our efforts in habitat protection and improvement, rabbit recovery programmes and captive breeding and reintroduction. It is also necessary to increase basic knowledge on lynx reproduction biology and in landscape ecology aspects. If we can use this knowledge to halt Iberian lynx's decline, then we can prevent their extinction, but is quite certain that is going to take decades to recover former populations, particularly in Portugal.

1.2 Status and distribution in Spain

1.2.1 The 1988 survey

In Spain, during the late 1980-s, a national study was carried out with the goal of describing the distribution and regional variations in the abundance of the Iberian lynx. This survey was based on a combination of postal enquiries and personal interviews in the field, using sighting data from the period of 1978-1988 (Rodriguez & Delibes, 1990).

The main results of this study were (from Delibes *et al.*, 2000):

1. The Iberian lynx presence was only detected in the South-western part of the Iberian Peninsula;

2. The species was essentially restricted to isolated areas above 1300 m, preferably covered with a mixture of Mediterranean scrubland and open grassland, where intensive land uses were absent;

3. The lynx range was restricted to 11 700 km^2 of breeding areas plus 3 900 km^2 of areas only transitorily used;

4. The populations were fragmented in 48 unequal sized breeding areas;

5. High lynx densities were only verified in 17% of the breeding range;

6. The estimated total Spanish population was about 880-1150 adult individuals, of which 350 were adult females;

8. Nine hypothetical populations were estimated (Figure 1; Table 1):

a) In the northern edge of the lynx range, three isolated populations: Sierra de Gata, Sierra de Gredos and Alto Alberche; which corresponded to 13% of the range and 8% of the total population size, occupying the Sistema Central, an east-west oriented mountain range in central Iberia;

b) One population in Sierra de San Pedro (5% range, 4% population size);

c) One significant central population, including Montes de Toledo, Villuercas, Siberia Extremeña, Montes del Guadiana, Valle de Alcudia, and the Eastern Sierra Morena (62% range and 71% population size);

d) Two populations in Central and Western Sierra Morena (together 12% range, 10% population size);

- one population in the Sierras Subbéticas (4% range, 2% population size), and

- the Doñana population (4% range, 4% population size).

1.2.2 The 2002 census

Since 1999 till 2002, an intensive field survey was conducted in Spain, using distinct criteria for estimating lynx abundance and distribution (Guzmán *et al.*, 2002). During this survey only reliable evidences were used to sample lynx presence (scats confirmed by DNA amplification and camera trapping proofs).

For this new survey, the following objectives were established:

1-To determine the present distribution area for the Iberian lynx, using objective surveying methods;

2-To intensify the field work in the most important areas defined by the 1988 survey: Toledo mountains, Eastern Sierra Morena and Doñana;

3-To define the highest possible number of breeding females territories;

4-To estimate the minimum lynx numbers in areas of regular presence;

5-To study the distribution and abundance of rabbit populations within the lynx historical range;

6-To evaluate habitat suitability for lynx and to identify threat factors in the lynx areas;

7-To evaluate the evolution of lynx populations and its current tendency.

Major conclusions of this survey pointed out to a dramatic situation, with most of the populations identified during the 1988 survey not being detected. The species was considered in the brink of extinction and the IUCN listed the Iberian lynx as critically endangered. According to Guzmán *et al.* (2002), the lynx currently occupies about 350 km^2, in only two identified populations: Doñana and Cardeña-Andújar (Figure 2).

In the estimated area, only 200 individuals were believe to survive. The Doñana population was estimated in about 30-35 lynxes (3-5 breeding females) and 90-120 individuals (25 breeding females) were estimated for the Cardeña-Andújar population.

1.3. The status of the Iberian lynx in Portugal

1.3.1 The 1998 census

From 1994 to 1997, a survey on the status of the Iberian lynx in Portugal was undertaken using the same field methods of the 1988 lynx Spanish survey (Ceia *et al*, 1998). Although some reports referred to dead animals (testable), the most common kind of information (sightings) was obtained indirectly from interviews in the field.

Figure 1 – Geographic distribution of Iberian lynx populations according to the data of Rodriguez & Delibes (1990) (Spain) and Ceia *et al.* (1998) (Portugal). 1 - Algarve-Odemira-Sado Valley; 2- Gata-Malcata-San Pedro-S.Mamede; 3- W.Sierra Morena-Guadiana; 4- Alberche; 5- Gredos; 6- Subbéticas; 7- Doñana; 8 -Central Sierra Morena; 9- Central population.

As result of this study, five lynx populations were identified, spread throughout 2400 km^2 and harbour a total population of 40-53 individuals. Three areas (Serra da Malcata, Serra de São Mamede and Guadiana Valley) were western extensions of the Sierra de Gata, Sierra de San Pedro, and Western Sierra Morena Spanish populations, respectively (Figure 1). All these populations had declined in the last decades and probably did not contain more than 10 individuals each. Occasional reports pointed to a possible communication between the international populations of Gata-Malcata and San Pedro-São Mamede, at the Portuguese side of the border (Figure 1).

The most important Portuguese lynx region was considered Algarve-Odemira, in the Southern end of the country. There, reports were distributed in four relatively large and three small nuclei that summed up some 940 km^2. Numbers have declined and no more than 25 animals were believed to live there at low density. A remnant population seemed to persist in South-western Portugal associated to the Sado river basin, probably connected through dispersing animals with the Algarve-Odemira population, totalling some 1300 km^2 and up to 30 lynx (Figure 1; Table 1).

Figure 2 – Geographic distribution of Iberian lynx in Spain according to the most recent data (Guzmán *et al.*, 2002). 1- Doñana; 2 – Cardeña-Andujár.

Although the report of 1998 (Ceia *et al.*, 1998) pointed out, to Portugal, the existence of reproductive populations and towards the viability of the Algarve-Odemira nucleus, several studies conducted at the same period, and based on more rigorous criteria, did not validate that census.

Sarmento *et al.* (2001) after two years of applying several detection techniques (box-trapping, camera-trapping, snow-tracking, scent stations and hair snares) were unable to detect a single animal in Serra da Malcata and Pinto (2000), in is evaluation of the lynx status in South-western Portugal, describes an incompatible situation with the population estimates of the 1998 census (Ceia *et al*,1998).

Years later, these facts were clarified with the presentation of the conclusions of an extensive study, based on DNA analyses from potential lynx excrements, collected from 1994 to 2000 (Pires & Fernandes, 2001). Only two scats, found in Serra da Malcata, in 1997, were confirmed as lynx origin.

Table 1: Past status of Iberian lynx populations by countries (from Delibes *et al.* 2000). Numbers identifying populations correspond to those in Figure 1. Populations shown in the table are really metapopulations or groups of populations connected through a variable flux of dispersing individuals. In third column, “Country” refers to Portugal (P) and “Regions” to Spanish autonomous regions (AND = Andalucía, CLE = Castilla-León, CLA = Castilla-la-Mancha, EXT = Extremadura, MAD = Madrid). Number of lynx, areas and densities are approximated figures. Estimation methods: fi = field inquiries by means of interviews or questionnaires, fs = occasional search of field signs, rt = radio-tracking. Trend: S= stable. D= decreasing, **?** = unknown.

Country Population	Country or Region(s)	# of lynx	Total Area (km2)	Mean density (ind/100km2)	Estimation method	Population trend
PORTUGAL						
1 Algarve-Odemira-Sado Valley	P	25-30	1300	1.6-2.2	Fi,, Fs	D
PORTUGALSPAIN						
2 Gata-Malcata-San Pedro-S.Mamede	P-EXT-CLE	75-95	2050	1.7-4.6	Fi, Fs	D
3 W.Sierra Morena-Guadiana	P-AND-EXT	40-45	1300	1.9-3.5	Fi, Fs	D
SPAIN						
4 Alberche	MAD	5-10	270	1.9-3.7	Fi, Fs	D
5 Gredos	CLE	8-12	370	2.2-3.2	Fi, Fs	D
6 Subbéticas	AND	25-30	540	4.6-5.6	Fi Fs	**?**
7 Doñana	AND	40-50	540	7.4-9.3	Fs, Rt	S
8 Central Sierra Morena	AND	60-65	760	7.9-8.6	Fi, Fs	**?**
9 Central Population (E.S.Morena-Montes de Toledo-Villuercas)	AND-CMA-EXT	350-450	9100	3.8-4.9	Fi Fs	D

1.4 The problem

When we analyse the facts pointed above, it is clear that a similar situation, to the one described for the lynx Spanish populations, was occurring in Portugal. The results obtained by personal interviews were not confirmed by field studies and so two explanations could be suggested:

- the estimates made in the 1998 survey were too optimistic;
- the population size has decreased remarkably during the last five years.

In late 2001, the Institute of Nature Conservation (ICN), aware of the critical status of the Iberian lynx in Portugal, elaborated a document for emergency actions to prevent the species extinction. Priority decisions consisted in evaluating the status of remnant populations and to define potential areas for capturing individuals for captive breeding and a genetic reserve.

1.5 The 2002 census

A national operation was started in early 2002, after an agreement with the Spanish Dirección General de Conservación de la Naturaleza (DGCN) for using the same lynx monitoring methods in order to evaluate the species status in all of its range. The following objectives were established:

1- To design a baseline of status and distribution of the species for result comparison of subsequent surveys on a national scale;
5- To develop a simple and reliable method of collecting information to facilitate future surveys;
6- To analyse rabbit distribution and abundance within the lynx historical range;
7- To define potential areas for capturing founders for the captive breeding programme.

In this report we describe the results of a two years field survey on the status of the Iberian lynx in Portugal. We compare current situation with previous surveys and we point out conservation measures for saving the species from extinction in the country.

2. METHODS

2.1 Creating the system

Detecting changes in abundance on endangered species is a key issue for their conservation and for a basis of decision making in wildlife management. Because of their relatively low population sizes and elusive nature, carnivores are notoriously difficult to survey. Fortunately, sophisticated non-invasive methodologies for furthering our knowledge of carnivores are increasingly available. The cost-effective development of biochemical techniques, such as DNA analyses, permits accurate identification of an individual animal from remains such as scats and shed hairs. Camera-trap photography, track plates, scent stations, hair snagging, and genetic analyses can now be used in conjunction with traditional techniques -- such as snow tracking, trapping, and radio-telemetry -- to monitor carnivores. Because no single survey method is suitable for all species, we are using a suite of non-invasive techniques, found to be effective in Iberian lynx (Guzmán *et al.*, 2002) and other feline species. One important issue when sampling such a rare species as the Iberian lynx is using a method with high reliability that could detect, with substantial precision, presence and declines in population size. So, we decided not to use sighting reports as proofs of lynx existence since this method tends to give a fictional scenario of lynx numbers (Guzmán *et al.*, 2002). Personal interviews and questionnaires most times including misidentification of lynx, considerable errors on the sighting date and place.

For conducting this survey, we choose a combination of methods with high reliability and that could constitute a suitable data base for future lynx conservation. These methods were:

1- Sign searching;
2- Camera trapping;
3- Box trapping.

2.2 Sign searching techniques

The sign searching methodology was conducted using a geographic framework of 10 x 10 km UTM grid squares, defined upon lynx historical range estimated by previous studies (Palma, 1980; Ceia *et al.*, 1998) (Figure 3). For the survey we also incorporated several areas of lynx potential habitat outside its previously defined range (Figure 3). The field work consisted of a search for signs of lynx and rabbit presence and was undertaken between January 2002 and May 2003.

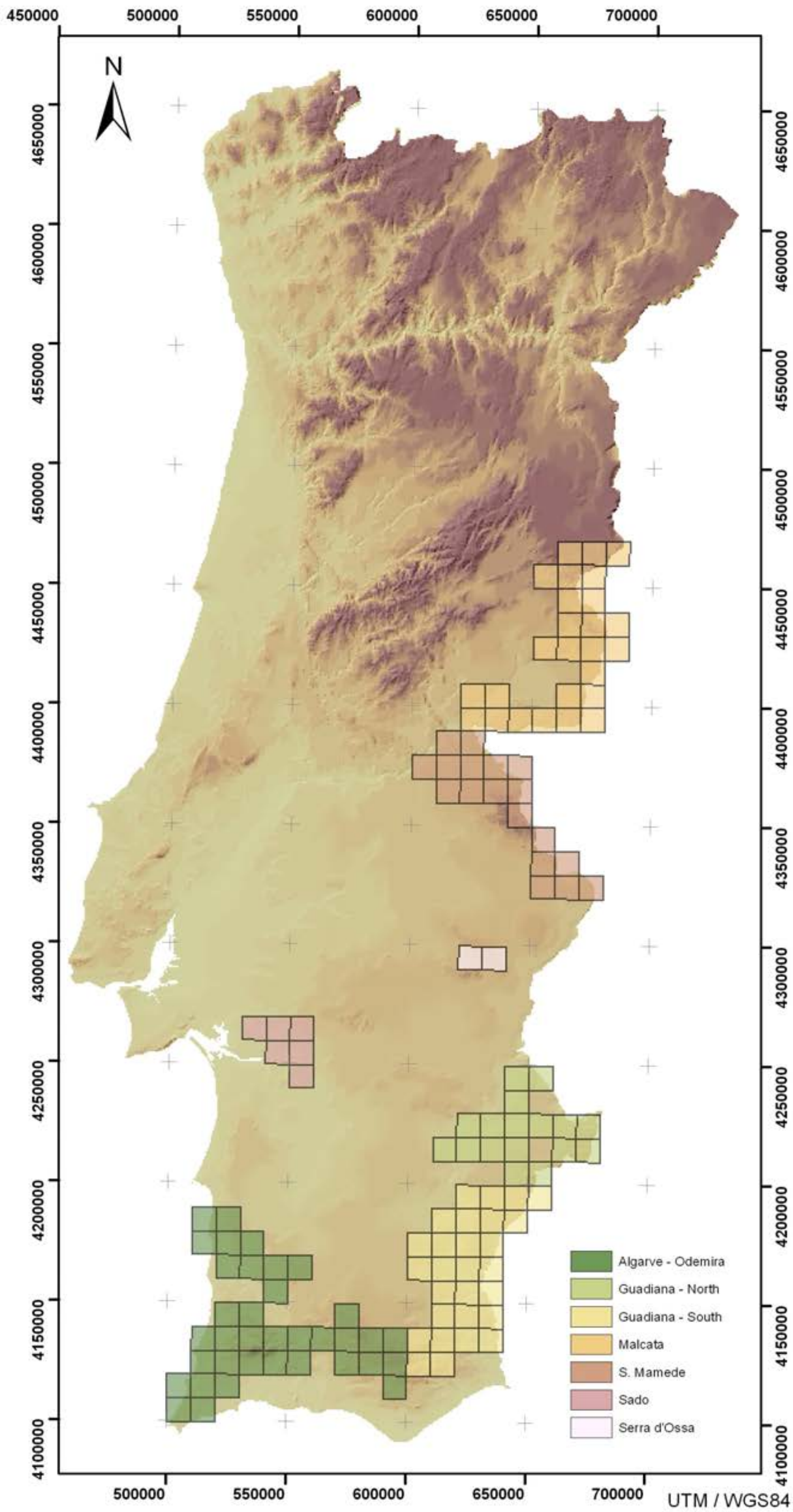

Figure 3 – UTM squares (10 x 10 km) surveyed for lynx presence during the current study.

2.2.1 Focus zones

In order to augment the probability of obtaining positive results and to obtain a more coarse-grain survey, we defined focus zones inside the UTM squares (Photograph 1). Focus zones are areas of particular interest where intensive effort was conducted; they are irregular in shape and they present natural characteristics suitable for lynx, namely:

1- Presence of Mediterranean scrubland patches with areas superior to 100 hectares;
2- Potential ecological corridors between suitable patches;
3- Medium or high rabbit density.

▲**Photograph 1 –** Example of a focus zone on a sampled UTM square (10 x 10 km).

Focus zones were defined using the criteria of Palomares (2001) which describes an ideal habitat for lynx.

2.2.2 Collected data

Lynx

In focus zones searching efforts were conducted on roads, trails and rocky areas since the lynx uses mostly these spots for territorial marking. Mudded areas and snow covered territories (North range) were also searched for potential tracks.

When a potential sign was detected, its UTM geographic coordinates were recorded using a GPS navigator and deposition location was characterized by recording the following data, in a 20 m radium circle: 1) percentage of rocky cover; 2) percentage of grass cover; 3) percentage of shrub cover; 4) percentage of tree cover; 5) trees species. Percentage class were defined using the following scale:

0 (0%); 1 (1-10%); 2 (11-20%); 3 (21-40%); 4 (41-60%); 5 (61-80%); 6 (81-100%)

Lynx potential scats (Photograph 2)were collected using a protocol suitable for DNA analyses, in order to determinate their specific taxonomic origin (Palomares *et al.*, 2000; Pires & Fernandes, 2001).

Recent advances in DNA techniques have opened the door for more accurate assessment of lynx distribution and so in the current project we gave emphasis to this methodology.
Scatological DNA analysis were performed in the following laboratories: Doñana Biological Station (Sevilla, Spain), Cáceres School of Veterinary (Cáceres, Spain), Laboratory of Genomic Diversity (Washington, USA).

▲**Photograph 2 –** Potential lynx scat.

Rabbit

Rabbit presence and density was obtained by counting latrines within the established transects on the focus zones. Latrines were divided into three groups according to the number of estimated pellets (Sarmento *et al.*, 2001): 1) type I – 1- 50 pellets; 2) type II – 51 to 125 pellets; 3) type III - > 125 pellets. Then, we use the index of rabbit abundance (RI) described in Sarmento *et al.* (2001), which is:

$$RI = \frac{12.510\ TIII + 5.10\ TII + TI}{CE}, \text{ being:}$$

TIII – number of type III latrines; TII – number of type II latrines; TI – number of type I latrines; CE – covered space.

Using the RI, we convert the data in rabbit abundance classes which were ranked using the following scale:

Class 0:RI = 0 - not detected
Class 1. RI from 1 to 10 - Low density
Class 2 . RI from 11 to 40: Low medium density
Class 3. RI from 41 to 70: High medium density
Class 4 . RI from 71 to 100: High density
Class 5. RI > 100: Very high density

Using the data obtained during the field work, conducted in Malcata since 1999 (Sarmento *et al*, 2003), we related the described scale with estimated rabbit densities, this procedure allowed us to establish density intervals for each class and potential implication upon lynx territorial behaviour (Palomares., 2001)(Table 2).

Table 2: Relation between rabbit abundance classes, estimated rabbit density and lynx social classes (from Sarmento *et al.*, 2001).

Class	RI	Estimated rabbit density (animals/he)	Estimated lynx response
0	0	0	Absent/vagrants
1	1-10	>0-0.75	Vagrants
2	11-40	0.75-2.0	Vagrants
3	41-70	2.0-4.5	Residents
4	71-100	4.5-10	Reproduction
5	>100	>10	Reproduction

2.2.3 Sampling effort

The sampling effort per square was defined according to the size of focus zones. Guzmán *et al.* (2002), on their status survey of Iberian lynx in Spain, established a minimum effort of 8 man/hour per square. For this work, we decided to calculate the sampling effort using previous field experiences. Using a GPS navigator, we determined the medium velocity of a field assistant and travelled distances in different size focus zones and, in order to obtain a suitable sampling, in different squares, we created a reference table (Table 3) that relates the percentage of suitable habitat with the minimum effort for a reliable sampling.

Table 3: Reference table to determine the minimum effort per square according to the percentage of suitable habitat.

% of potential habitat	Minimum effort (man/hour)	Estimated distance sampled
<10	4	17.2
11-20%	6	25.8
21-40	9	34.4
41-60	12	51.6
61-80	16	68.8
81-100	18	77.4

2.3 Camera trapping

The use of camera traps to detect elusive mammals, such as carnivores, has proved to be highly efficient (Cutler & Swann, 1999). The technique has the advantage of being cost-effective and providing positive species identification. Another advantage is the low perturbation effect in detecting cryptical animals with inconspicuous habits (Zielinsky *et al*, 1995). Currently, photographic trapping is successfully used in Spain, in the Iberian lynx national census and in other ecological studies (Guzman *et al.*, 2002), and is gaining popularity as a suitable method for this species detection. Recent results, obtained in Spain, attributed to this technique a substantial importance on determine lynx abundance and presence, since animals can be identified by natural features (e.g., pelage characteristics) which is an evidence that camera-trapping survey methodology is reliable for the purpose at hand.

2.3.1 Photographic devices

Two distinct camera devices were used: pressure plate triggering device (Photograph 3) and sensor heat activated CamTracker®(Photograph 4). In the first camera system the triggering device is as pressurised plate (dimensions of 30 × 30 cm) which is connected to a simple 35 mm automatic camera (equipped with fixed great angular objective and automatic flash), through an electric wire buried in the ground. The plate is protected by a hermetic plastic bag to avoid damages to the system due to humidity. The circuit inside is opened. When an animal steps on the plate, closes the circuit the camera shoots a photograph. The set device is placed inside a wooden box opened at the front to avoid direct impact by the rain and sun. The camera is set at about 15 cm height (average) above the ground and distanced 2 to 4 meters of the pressure plate. This system is equivalent to the one described by York (1996) and used in Spain by Guzman *et al.* (2002).

▲**Photograph 3** – Pressure plate camera trap used for lynx detection.

The second photographic system is totally automatic and the photograph shots are activated by differences of intensity of heat. The sensor memorizes the temperature in the detection area and when a heat source makes the temperature vary the camera is activated and a photograph is taken. The sensor is associated to a 35 mm camera with similar characteristics to the one described above. The unit is compact and is protected by a water-resistant container. The sensor was programmed to detect 24 hours/day and once activated a photograph is shot every

20 seconds until the temperature returns to normal. The attractant was distanced 2 to 4 meters from the camera.

2.3.2 Attractants

The attractant scent station consisted in a wooden stake with a piece of cork-tree (*Quercus suber*) bark attached at 40-50 cm above the ground (Guzman *et al.*, 2002). The lure was sprayed on the bark.

The lure used in the scent-stations, associated to the camera-traps, was Iberian lynx urine which, according to Guzmán *et al.* (2002), is considered to be the most effective attractant for the species. A scent lure was preferred instead of food-bait, in order to avoid the deterioration of the station and the attraction of non-target species (which could eat or destroy the bait-station). Another disadvantage of the use of food-bait is the possible contamination of the target species with pathogens due to bait degradation.

Photograph 4 – CamTracker® device used during the current study.▲

The Iberian lynx urine was kindly offered by the Doñana National Park lynx team and was collected from captive specimens held in El Acebuche reproduction centre.

2.3.3 Target areas

The survey areas were selected by combining several factors such as a rabbit density compatible with lynx presence (Palomares, 2001), suitable habitat, proximity to known lynx populations (Cardeña-Andujár and Doñana) and location of potential lynx scats (sent for genetic confirmation) previously collected. By following this protocol the camera-trapping survey area was reduced to Serra da Malcata Natural Reserve (SMNR), Special Protection Area of Moura-Mourão-Barrancos and Vale do Guadiana Natural Park (VGNP).

Each potential study area was surveyed thoroughly with the help of skilled field staff to identify sites that were likely to be visited by lynxes. From among these potential trap-sites, about 50-60 sites, per study area, that showed high suitability for lynx use, were selected for camera trap sampling.

2.3.4 Camera placement

In trapping grid studies, trap spacing is usually established such that all animals moving in the grid interior are exposed to traps (Sanderson, 2002). In this study the cameras were placed in highly suitable areas, that presented the highest probability of being occupied by resident animals.

On the field, cameras were placed at 0.3 to 0.7 km apart (Guzman *et al.*, 2002) on trails and trail intersections and were maintained on the field for at least 28 days, which is the minimum described by Zielinsky *et al.* (1995) for the detection of carnivore species in low densities. A buffer area of half the species home-range (Carbone *et al.* 2001; Karanth & Nichols 2000) was calculated around the camera-traps to represent the total survey area covered by that set of photographic-traps. The effectively sampled area comprises the polygon enclosed by the camera trap locations on the perimeter and a 'buffer' area approximately equal in width to half the length of the home range of the animal species being studied (1.5 km) (Ferreras *et al.*, 1997).

2.3.5 Relative abundance of non-target species

Most non-target species cannot be identified as individuals and to estimate their relative abundance we used a relative abundance index (RAI). The number of photos cannot be used to determine population or compare abundance among sites over time. Sunquist & Sunquist (2003) have defined a detection unit of observation, or simply *detection*, as one photograph of a species per camera photo-trap per day (24 hours). If a male and female were detected this would count as two detections. If all photographs are taken of a single species in the course of a day, then this is counted as a single detection.

To compute the RAI for each species, all detections are summed for all camera phototraps over all days, multiplied by 100, and divided by the total number of camera phototrap days. For example, if 12 cameras are run for 180 days, then 12 * 180 = 2160 phototrap days. If 3 male and 4 female lynxes were photographed together each day for 90 days at a site. The lynx RAI would be computed as 7*90*100/(180*12) = 29.17. If a wildcat was photographed 8 times during a single day and twice on separate days, the wildcat's RAI = (1+2)*100/2160 = 0.139.

2.4 Box-trapping

Several methods of trapping have been applied for carnivore species such as padded foot-hold traps and snares and box-traps. Foot-hold traps have been used to capture Iberian lynx by a various number of authors (Castro, 1992; Palomares *et al.*, 2001), however, because of its possibility of inducing serious injuries on the captured species (Phillips, 1996) its use has been forbidden for capturing wild-living animals. Therefore, although box-trapping is not an injury free method it is the safest and commonest method used for capturing these kinds of felids (Palomares *et al.*, 2001; Kitchings & Story, 1984).

The cage-traps used were wire-cages with two guillotine doors activated by a pedal. The dimensions of the traps were approximately 180 × 80 × 80 cm (Photograph 5). A live pigeon was used as bait and was placed at the centre of the cage-trap inside a protection box. Tomahawk® live-traps 1.14 m × 0.38 m × 0.51 m were also used with a similar bait. Traps were disguised with natural vegetation such as *Cistus* spp. and the box floor was covered with dirt and herbaceous species in order to replicate a natural ground cover. Lynx urine was also used as scent lure to increase the capture probability.

As Iberian lynxes tend to use trails to move through their territory, the box-traps were placed in paths and trail intersections.

◄**Photograph 5** – Box-trap used during the trapping campaigns conducted in South-Guadiana.

Traps were visited everyday, at dawn, to avoid the exposure of the captured animals to high temperatures and to prevent an excessive stressful situation that could result in health complications.

Capture techniques were only applied in the South Guadiana valley areas, due to the possibility of capturing dispersing lynxes from the Doñana population.

2.5 Lynx detection probability

In a study of this nature it is crucial for researchers to estimate the detection probability of the target species in the surveyed area. We should take into account the possibility that one or more individuals are present in the surveyed area without being detected, neither by cameras or box-traps. Therefore the “detection probability” should be a reflection of the confidence that we have in the collected data.

During the Iberian lynx census, traps (both cameras and boxes) were placed on the field so that a minimum convex polygon (MCP) was formed by their relative positions. The method was standardized in order that the traps were placed between 300 and 700 meters from each other and the polygon that they formed covered, as much area as possible, of optimal lynx habitat.

As previously described, we determined an external buffer area around the polygons formed by trapping stations. Usually, the buffer width is determined as a function of the species activity or/and its home-range (Karanth & Nichols, 1998). Some authors use this distance as half of the furthest recorded photos of an individual specimen of the target species. Half of the diameter of the species home-range can also be used if the data is adequate (Carbone *et al*, 2002). However, these buffers are usually calculated with the purpose of determining a species density or abundance in the sampled area (Karanth & Nichols, 1998; Carbone *et al*, 2002). This fact means that positive results must be obtained during the survey and that, either we can identify animals individually, or photographic indexes must be directly correlated with the species density. Whatever the case should be, positive records of the target species presence must be collected.

In our study, the main objective is to use the same principle described above to determine the probability of recording the presence of a lynx present in the surveyed area. To attain this objective, random animal movements were simulated, using a similar process to the one described in Carbone *et al* (2002). We try to determine, for each sampled area, the detection probability assuming that one single Iberian lynx was present.

For this methodological approach, we used Iberian lynxes home-ranges sizes and average daily travelled distances from publish data, respecting the Doñana population (Ferreras *et al*, 1997; Palomares *et al*, 2001).

To obtain the total range of home-range areas, we applied the simulation to the smallest home-range described in literature (14.8 km^2)(described by Ferreras *et al*, 1997, for adult resident Iberian lynxes), and the to largest (36.8 km^2) (described by Ferreras *et al*, 1997, for subadult dispersant Iberian lynxes). The same principle was used for the average daily travelled distance. We simulated movements with the smallest and the largest average travelled distance per day described in literature, 6.4 and 8.7 km/day, respectively (Ferreras *et al*, 1997).

Since there was no way to determine the real shape of a possible resident Iberian lynx home-range, we considered it to be a circular area. Although this home-range shape does not represent a real situation, we assumed that no significant differences between values obtained using this method and a real situation should appear.

For this test, we assumed that all trap sets were placed on the field in such a way that the most suitable area for lynx was covered. The correspondence assumed, between trap placement and habitat suitability, allowed us to start every random walk from the centroid of the MCP, which should fall in a supposed core-area of the possible present animal.

We are fully aware that the values of probability obtained lack on statistical consistency, since they were obtained based in highly speculative presupposes, but they serve as reference to the confidence that we may have of this survey results.

All traps placed on the field were geo-referenced and projected in a GIS software (Arcview 3.2 ®). The MCP was drawn for each camera set and the respective centroid was determined. A circular buffer was created to represent a hypothetical Iberian lynx home-range. The following step in our procedure was to simulate several random daily movements within the "virtual home-range" drawn. Seven series of 100 random daily movements were simulated to determine the daily capture probability. For each set of 100 simulations the total number of transects that intercepted a 5 meter buffer around each trap was considered as a detection (we considered every transect that passed closer than 5 meters to a camera resulted in a positive record due to the scent station effect). The total number of contacts was calculated for the area in question and an average of the seven sets was then calculated for attaining a better confidence to the test results. This average represents the daily detection probability of each set of traps.

For each set of 100 simulations we used the following formula:

$$DP = \Sigma\, PC / 100$$

$$ADP = \Sigma\, DP / N$$

$$TDP = ADP \times NAD$$

Where:

PC – Positive records
DP – Daily detection probability
N – Total number of 100 sets of simulations
ADP – Averaged detection probability
TDP – Total detection probability

3. RESULTS

3.1 Sign survey – total sampling

Globally, a total of 133 UTM squares was sampled (Figure 4) with a total effort of 1975.79 man-hours and a total of 4252.17 sampled linear km (Table 4). The former lynx range, estimated in Ceia *et al.*(1998) corresponded to 89% of the sampled area. The field work resulted in the collection of 312 potential scats, from which 168 (54%) were considered valid for genetic analysis. No lynx detections were achieved with this method even in the previously classified viable population of Algarve-Odemira (Ceia *et al.*, 1998).

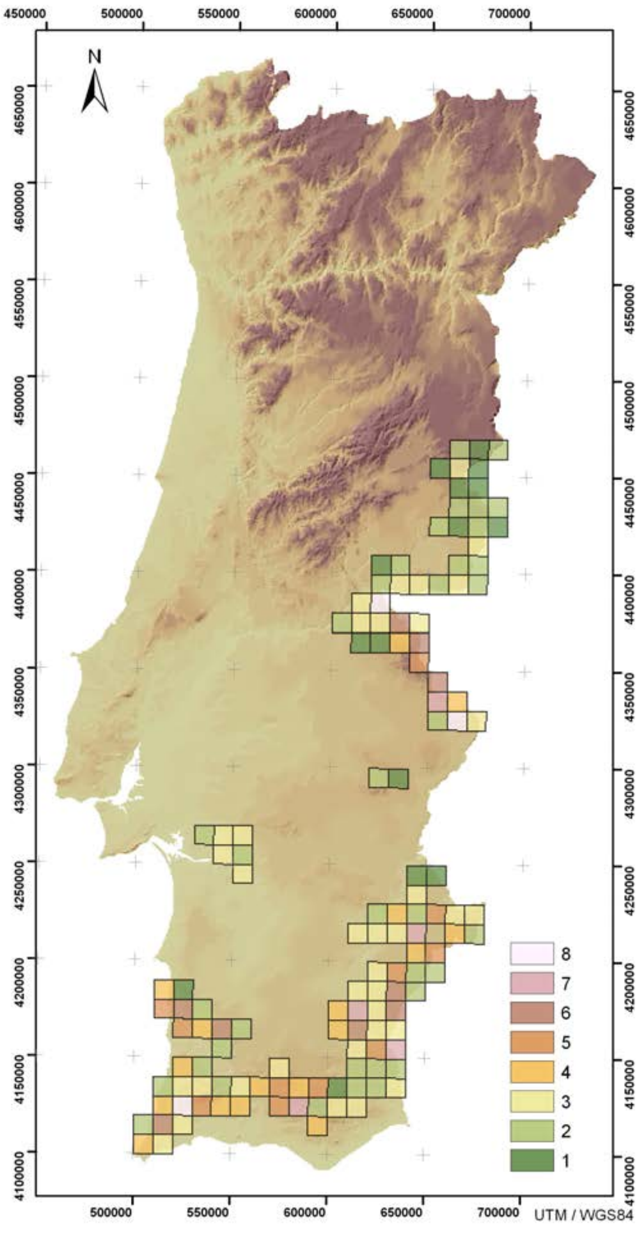

Figure 4 – Lynx surveying effort classes (man-hour) for the sampled 10 x 10 km UTM squares. Class 1- 1-5 man-hours; Class 2 - <5-10 man-hours; Class 3 - <10-15 man-hours; Class 4 - >15-20 man-hours; Class 5 - >20-25 man-hours; Class 6 - >25-30 man-hours; Class 7 - >30-35 man-hours; Class 8 - >35-40 man-hours.

Table 4: Sampling data from the different lynx nucleus submitted to field surveys.

	N squares	Estimated proportion of sampled square	Medium covered space per square (km)	Total covered space (km)	Medium effort per square (man-hour)	Total effort (man-hour)
Malcata-Tejo	26	17.2	20.56	352.51	7.79	257.65
Nisa-S.Mamede	18	25.8	11.06	122.06	4.94	170.29
Serra de Ossa	2	34.4	19.66	39.32	5.76	11.02
North Guadiana	17	35.29	16.43	533.80	8.56	215.52
South-Guadiana	28	49.85	25.21	1695.54	9.37	678.31
Algarve-Odemira	36	68.8	43.10	1465.54	17.24	586.61
Sado Valley	6	77.4	7.23	43.40	9.31	56.39
Total	**133**	**44.11**	**20.46**	**4 252.17**	**8.99**	**1 975.79**

3.2 Results per surveyed areas

3.2.1 Malcata-Tejo

Area description

The study area is located in central-eastern Portugal near the Spanish border, between 40º 08´50´´ N - 39º 59´00´´ N and 7º 22´55´´ W - 6º 50´00´´ W (Figure 5). The Northern part of this territory, includes the 164 Km^2 SMNR. Altitude ranges from 430 m to 1078 m. In this part, vegetation is dominated by dense scrublands of *Cytisus* spp., *Halimium* spp., *Cistus* spp., *Erica* spp., *Chameaspartium tridentatum*, and *Arbutus unedo*, throughout which scattered woodlands of *Quercus rotundifolia* and *Quercus pyrenaica* can be found. Significant parts of the area are covered by industrial plantations of *Pinus* spp., *Eucalyptus globulus* and *Pseudotsuga menziezii*. Agriculture fields cover a small part of the territory (Photograph 6).

◄**Photograph 6** – Area of Serra da Malcata managed for lynx conservation.

The Southern area is characterised by a lower altitude, with an average of 400 m, and vegetation is dominated by agriculture (mostly wheat) and industrial plantations, although scattered Mediterranean forests (dominated by *Q. rotundifolia*) can be found in several patches of the geographic area (Photograph 7).

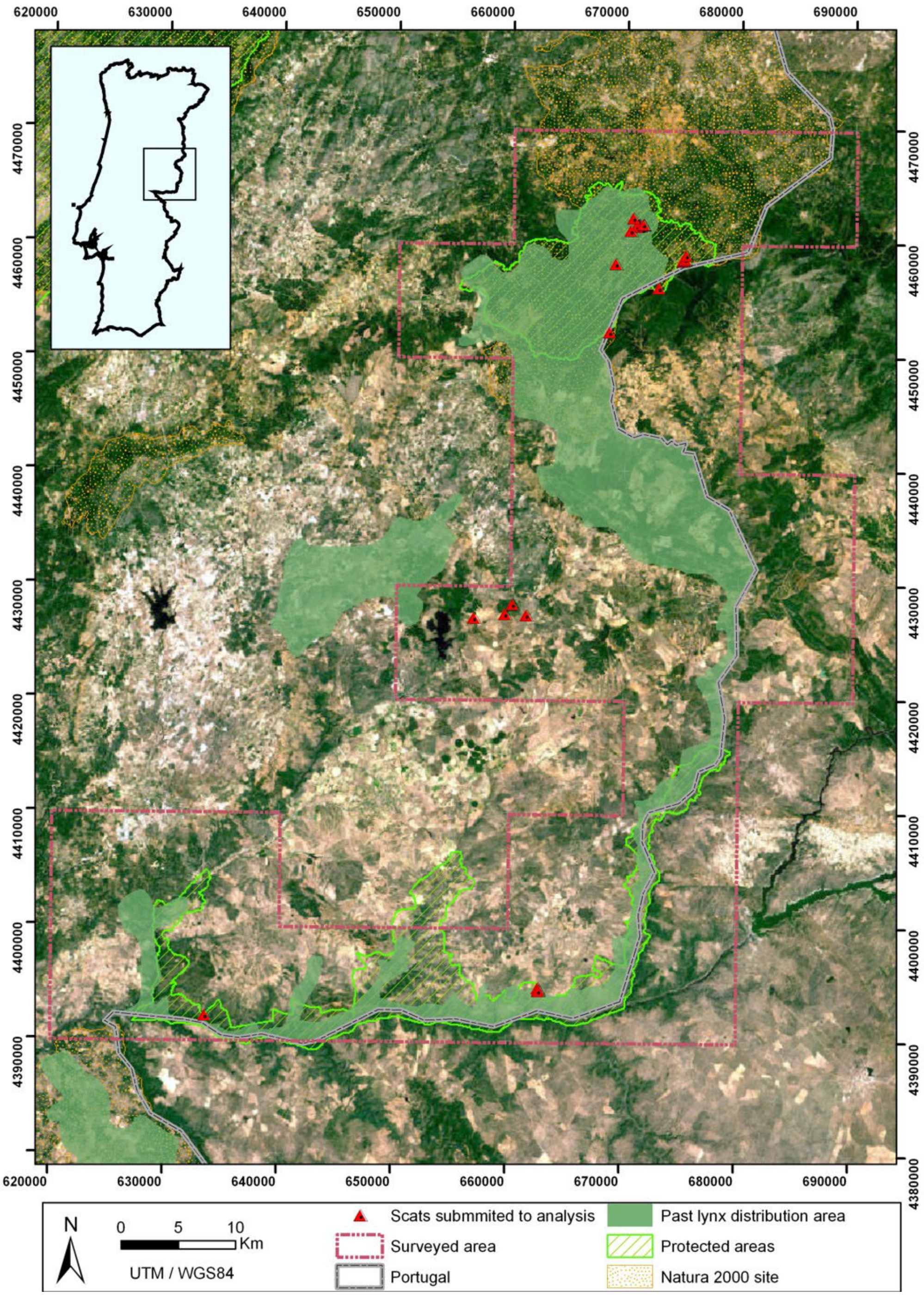

Figure 5- Malcata-Tejo study area: surveyed area, protected and classified areas, former lynx range (Ceia *at al.*, 1998) and geographic distribution of the potential lynx scats collected for genetic analysis.

Rabbit density and distribution

Rabbit distribution is extremely irregular and fragmented (Figure 6), exhibiting, in most squares, incompatible densities with the presence of resident lynxes (*n*=24, 92%). We observed a total of 2 231 latrines, with an average of 8.74 ± 0.18 per man-hour and an average abundance index (RI) of 18.06 (Figure 7). In a total of 7 UTM squares (28%) in which the lagomorph was not even detected and only 8% (*n*= 2) of the squares presented suitable rabbit densities for allowing lynx reproduction (Figure 6). These squares corresponded to the central part of Serra da Malcata Nature Reserve (photograph 6) and to a Mediterranean scrubland patch located in the Idanha-a-Nova plateau (Figure 6; photograph 7).

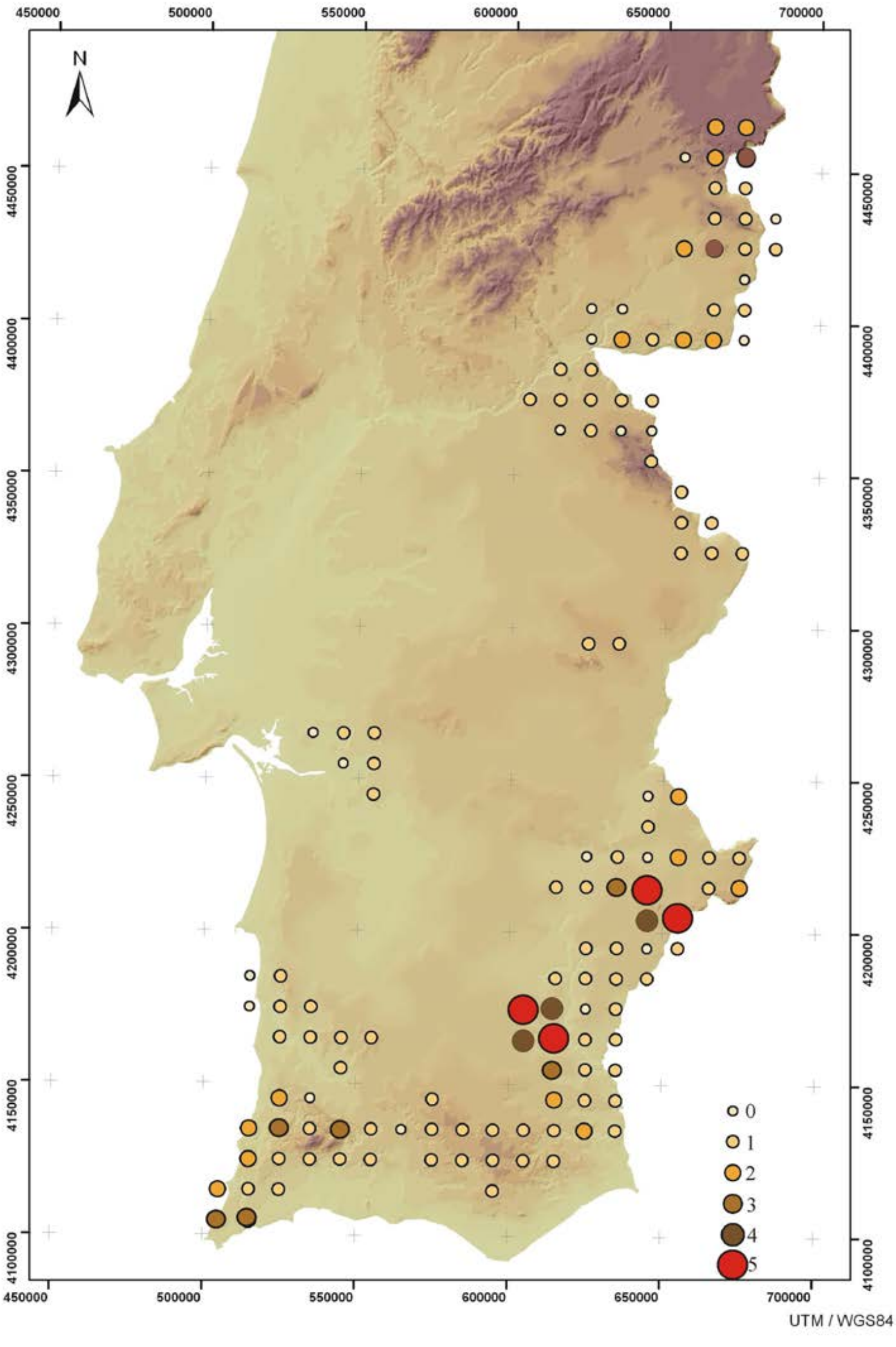

Figure 6 – Rabbit Abundance Index (RI) classes for each surveyed 10 x 10 Km UTM squares obtained during the current study. Rabbit abundance classes: **0** - not detected **1-** Low density; **2** Low medium density; **3**- High medium density; **4**- High density; **5.** -Very high density.

In the first area, although the altitude averages 1 000 metres, the landscape patterns are highly suitable for rabbits, since Mediterranean scrubland is intercepted with pasturelands and rabbit artificial shelters, as a result of an habitat management strategy applied during the EU Life project "Recovery of habitats and preys of the Iberian lynx in Serra da Malcata" (Photograph 6). In this area rabbit density is estimated in 4-5 rabbits/hectare (Sarmento *et al.*, 2003), which not only allows the presence of resident lynxes, but also reproduction.

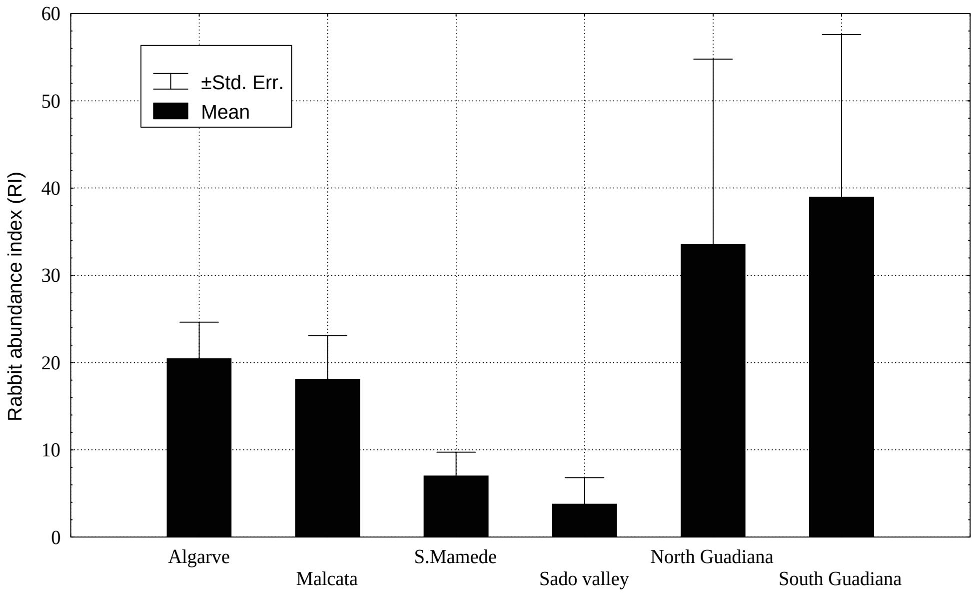

Figure 7 – Mean (± SE) Rabbit abundance index (RI) for the analysed Iberian lynx geographic areas.

The second area presents a distinct landscape structure. Pasturelands are scarce in a landscape dominated by Mediterranean scrubland, but the presence of isolated trees allows the existence of an understory cover with grass that can be used as food by rabbits, which is quite important to attain the verified high densities (Photograph 7).

▲**Photograph 7** – Mediterranean scrubland area of Idanha-a-Velha.

Sign search

This area, composed by a total of 26 10x10 km UTM squares, was surveyed from January 2002 to May 2003, in three sampling stages (January-February 2002; August 2002, February 2003). All the squares identified in Ceia *et al.* (1998) with lynx presence were surveyed, except the highly degradated area of Proença-a-Velha (Figure 5). A global effort of 257.65 man-hours of systematic sampling (Table 4) was applied and 103 potential feline scats were collect, being 36 of these (35%) selected as suitable for DNA analyses (average 0.72 per square, SE = 0.51, *n* = 26, range 0-5). It was not possible to obtain lynx positive amplifications (Figure 5).

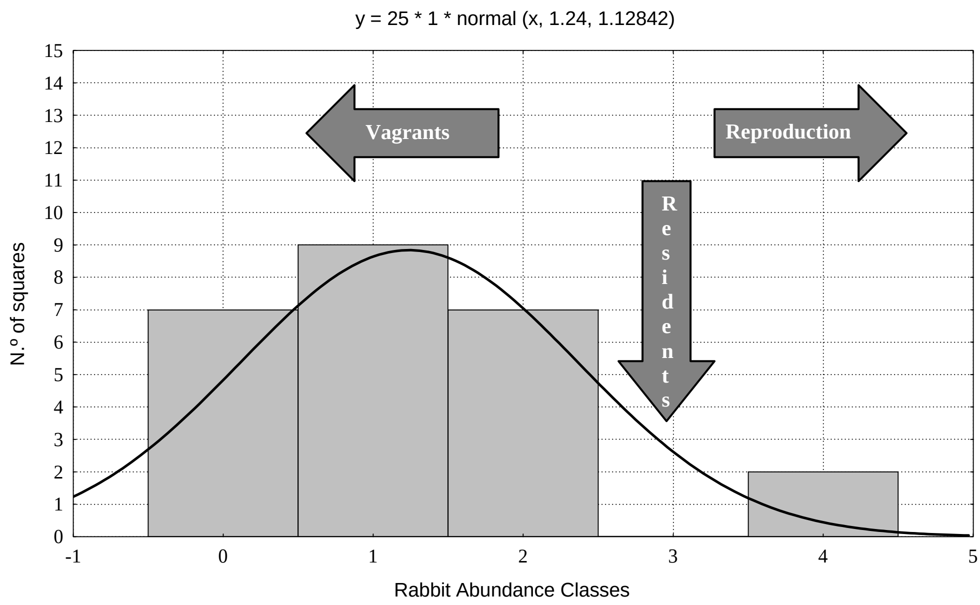

Figure 8 –Rabbit abundance classes histogram for the surveyed 10x10 km UTM squares of Malcata. Arrows indicate the theoretical lynx social class that could be present in each class.

Camera trapping

Camera placing and effort

Camera trapping was applied in an extensive area inside the 168 km^2 Serra da Malcata Nature Reserve (Figure 9). Cameras were continuously on the field since January 2002 to July 2003, comprising a total of 1465 camera-days for a total of 53 camera-stations (Figure 9). The area covered by the camera polygons and respective buffer areas, was 67.95 km^2, which corresponds to 75% of the potential lynx habitat in that protected area. All the areas that presented rabbit densities compatible with lynx reproduction and/or presence (Palomares, 2001) were camera surveyed.

Carnivore detections

No lynx detection were obtained, although four carnivore species were photographed in a total of 45 stations (85%) (Table 5). The camera trapping campaigns yielded 56 red fox (*Vulpes vulpes*) events, being this species detected in 39% of the stations and presented a RAI of 8.56 (Table 5). Other detected carnivores corresponded to small sized generalist species, which are common in this geographic area (Table 5, Annex I).

Lynx detection probability

Considering both the described scenarios, on chapter 2.5 (largest and smallest theoretical home-range areas), our model, based on random walks simulations, gave us a strong probability of detecting, at least, one resident lynx (>99%).

Table 5: Camera trapping data for the geographic area of Malcata. Ns –number of positive stations. Nd/100 d-c – number of detections per 100 camera-days. RAI- relative abundance index.

	Ns	%	Nd/100 d-c	RAI
Stone marten *Martes foina*	12	21	0.82	0.82
Iberian lynx	**0**	**0**	**0.00**	**0.00**
Red fox	22	39	0.00	8.56
Genet *Genetta genetta*	12	21	1.50	3.14
Egyptian mongoose *Herpestes ichneumon*	10	19	0.82	1.16

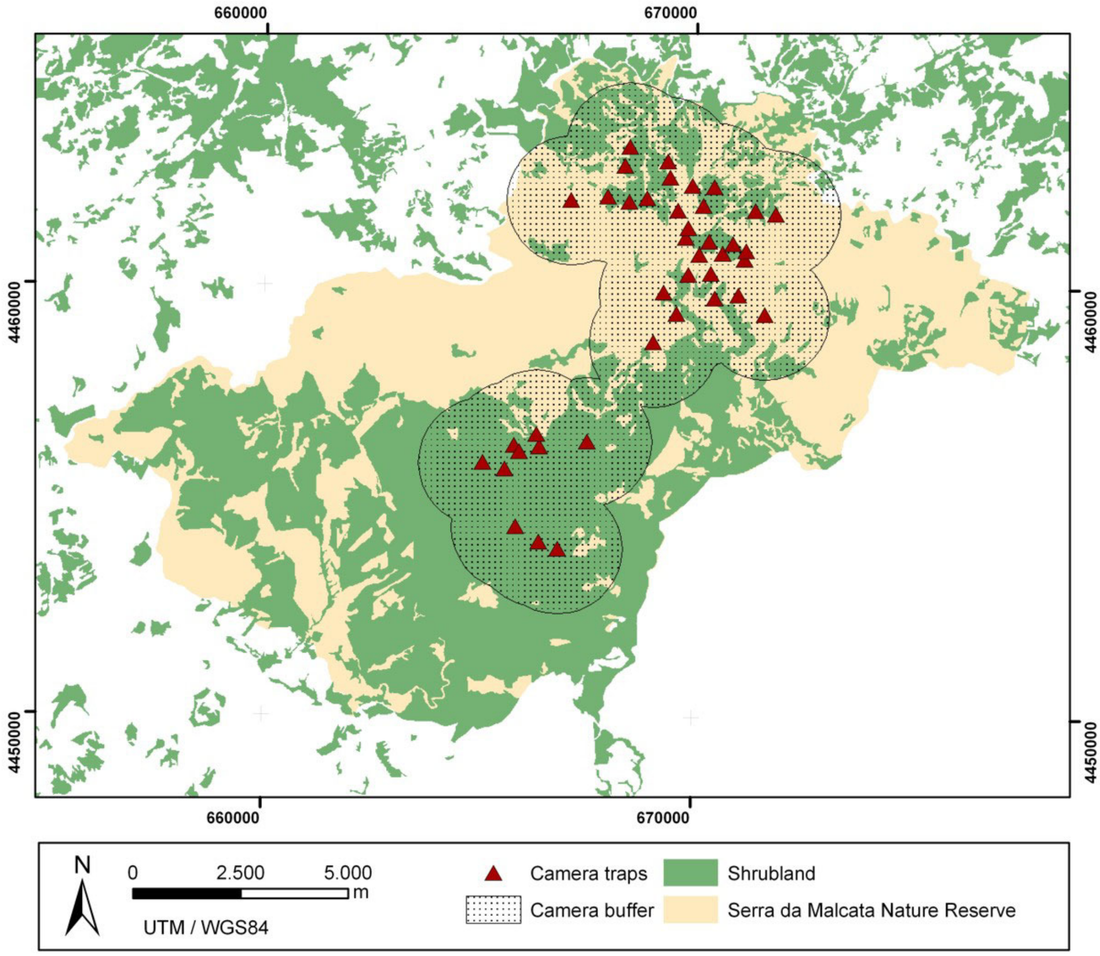

Figure 9- Trapping polygon and buffer area for the camera-trapping lynx survey in Serra da Malcata.

3.2.2 Nisa-S.Mamede and Serra de Ossa

Area description

This study area, located between 39º 39´74´´ N - 39º 00´45´´ N and 7º 32´38´´ W - 7º 15´54´´ W, has a vegetation characterised by the presence of autochthonous Mediterranean scrubland formations, where *Cystus ladanifer* and *Halimium halimifolium* shrubs predominate, with scattered trees in between, mainly *Quercus suber* and *Quercus rotundifolia*. Surrounding these areas are both cultivated forests (*Pinus* spp.or *Eucalyptus* sp.) with low understory coverage, and agriculture land (Photograph 8, Figure 10). A small amount of this area is under protection being included in S. Mamede Natural Park (Figure 10).

▲**Photograph 8** – Typical landscape aspect of S. Mamede study area.

Vegetation in Serra de Ossa (38º 56´26´´ N - 38º 47´895´´ N and 7º 15´22´´ W - 7º 06´56´´ W), in the oriental range of the area, is dominated by intensive plantations of Eucalyptus species and in the western range, well preserved formations of Mediterranean forest are the main vegetation type (Photograph 9, Figure 11).

Rabbit density and distribution

In S. Mamede surveyed area, rabbit abundance indexes ranged between 0 and 9.75, averaging in 7.01 (SE= 6.08, *n* = 11) (Figure 7). The species distribution presents an highly irregular patron and rabbits were not detected in three (17%) of the prospected UTM squares (Figure 6 and 12). Most of the area is unsuitable for rabbits since is covered by intensive industrial plantations and cattle farms. Rabbits appeared in low density in Mediterranean scrubland areas. We mapped a total of 294 rabbit latrines with an average of 26.73 latrines per square (SE =24.71, *n*= 11, range = 0-83).

During the field work, no warrens were detected, neither rabbits were observed, which is an indicator of a vestigial density which, according to literature (Palomares, 2001), can not allow the presence of resident lynxes (Figure 12).

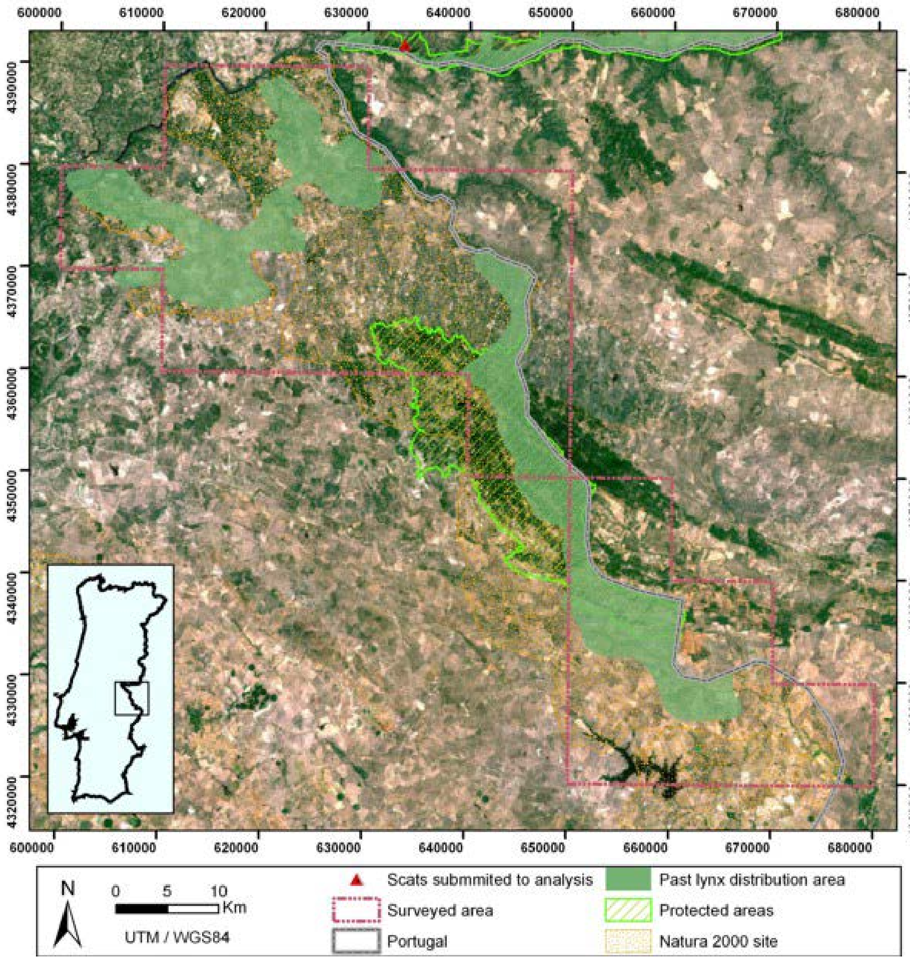

Figure 10- S. Mamede study area: surveyed area, protected and classified areas, former lynx range (Ceia *at al.*, 1998) and geographic distribution of the potential lynx scats collected for genetic analysis.

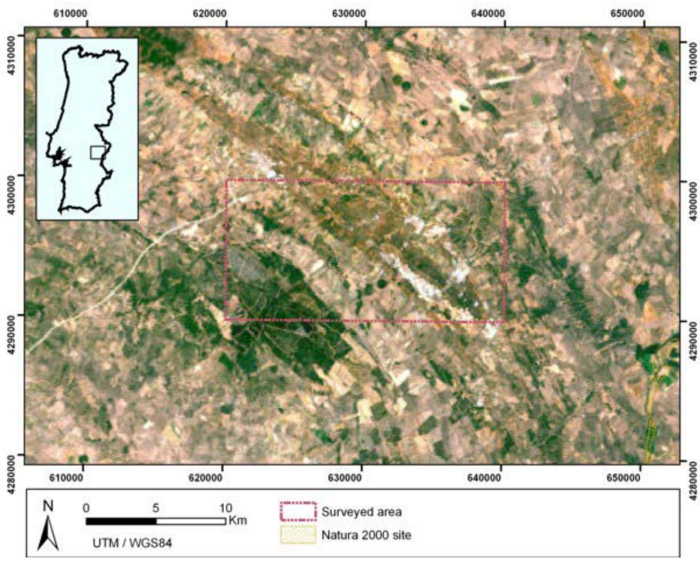

Figure 11- Serra de Ossa surveyed area.

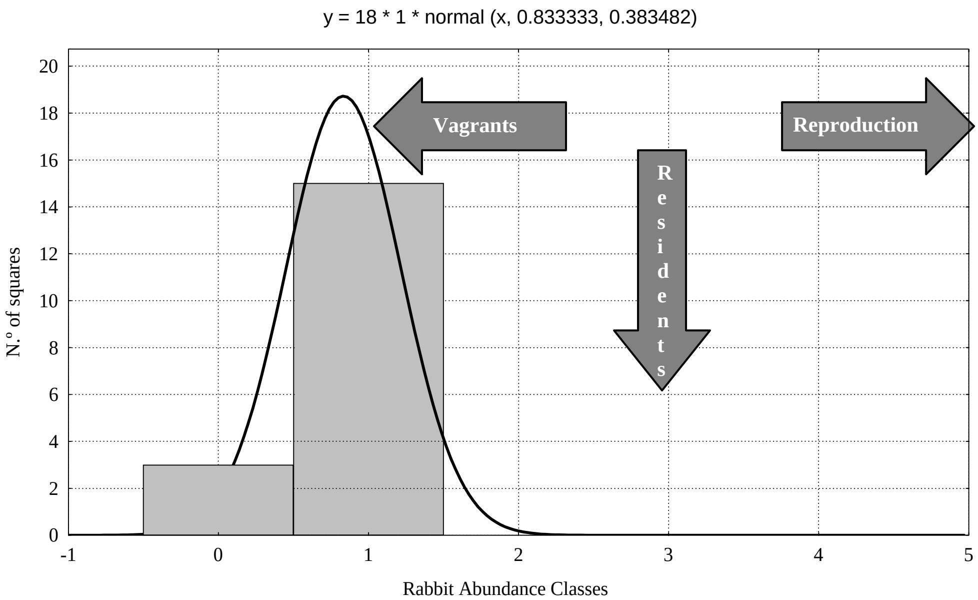

Figure 12 –Rabbit abundance classes histogram for the surveyed 10x10 km UTM squares of S. Mamede. Arrows indicate the theoretical lynx social class that could be present in each class.

Sign search

This area, composed by a total of 18 10x10 km UTM squares, was surveyed during January and February 2002. All the squares identified in Ceia *et al.* (1998) as lynx presence were surveyed. A global effort of 170 man-hours of systematic sampling was applied (Table 4) and 8 potential feline scats were collected, being 4 of these (50%) submitted to DNA analyses (average = 0.22 scats per square, SE = 0.10, *n* = 18, range 0-2) (Figure 10) with no positive lynx amplifications.

▲**Photograph 9** – Natural vegetation that dominates the occidental slopes of Serra de Ossa.

Due to the poor lynx presence evidences, this area was not submitted to other types of detections methods such as camera trapping.

For Serra de Ossa, after a searching effort of 11.02 man-hours (Table 4) no potential scats were collected (Figure 11).

3.2.3 North Guadiana

Area description

This study area (Figure 13), located between 38º 11´91´´ N - 37º 58´82´´ N and 7º 13´97´´ W - 7º 16´86´´ W is a rather flat area, intercepted by the sub-parallel linear valleys of the Guadiana tributaries (Ardila and Murtigão) that flow eastwards from their sources to the Guadiana river. Landscape is dominated by intensive agriculture fields and lynx habitats are mostly concentrated in the south (Adiça mountain complex) (Photograph 10) and eastern range of the area (Contenda-Barrancos). These areas are dominated by associations of *Quercus rotundifolia* and *Juniperus turbinata ssp* that cover the upper areas of the Adiça complex (Ficalhos, Adiça. Preguiça and Belmeque), forming an extremely suitable habitat for lynx, since open areas are combined with a medium evolved vegetation that allows the presence of high rabbit densities. In the Eastern areas, natural vegetation is thicker and dominated the *Cystus* species. Here the herbivorous community is dominated by ungulates that appears in high densities such as red deers (*Cerpuhs elaphus*), wild boars (*Sus scrofa*) and mouflons (*Ovis mouflon*).

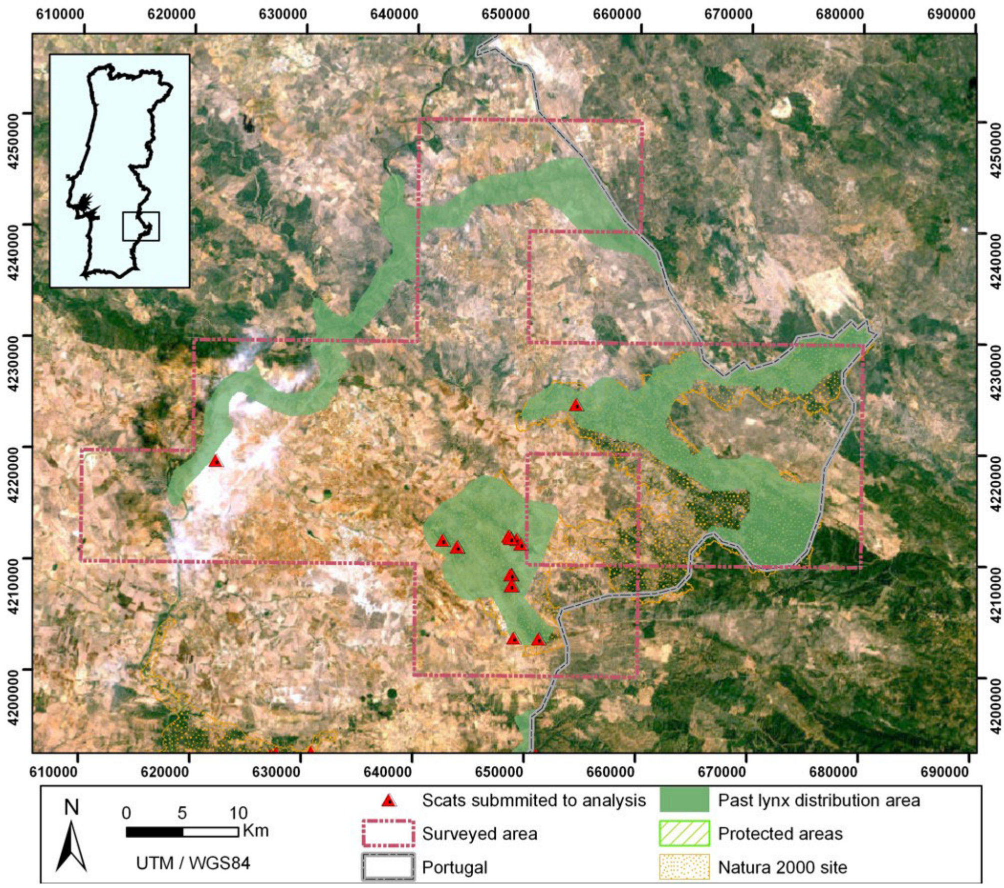

Figure 13- North-Guadiana study area: surveyed area, protected and classified areas, former lynx range (Ceia *at al.*, 1998) and geographic distribution of the potential lynx scats collected for genetic analysis.

Rabbit density and distribution

We obtained an average rabbit abundance index (RI) of 33.52 (SE= 23.51, *n* = 17, range 0-220) (Figure 7). A total of 2 375 rabbits latrines was counted, which corresponds to an average of 49.06 latrines per man-hour (SE = 32.71, *n* = 215.52, range 0-593). Inside this area, rabbit distribution is extremely irregular, being this species more concentrated in the southern part of this territory (squares Adiça-Ficalho) where it reaches high densities that could allow lynx reproduction (Figure 6). Within this class, we identified three potential squares were lynxes can settle and breed (Figure 14). In this area, during the conduction of the field work, 96 rabbit were observed and a significant amount of warrens was detected. Rabbits are more abundant and concentrated in the well-preserved scrubland habitats.

In the North-eastern areas, although habitat features are suitable for high rabbit densities, the species appears in low densities or is even absent. This situation happens mostly in areas were red deers and mouflons are extremely abundant.

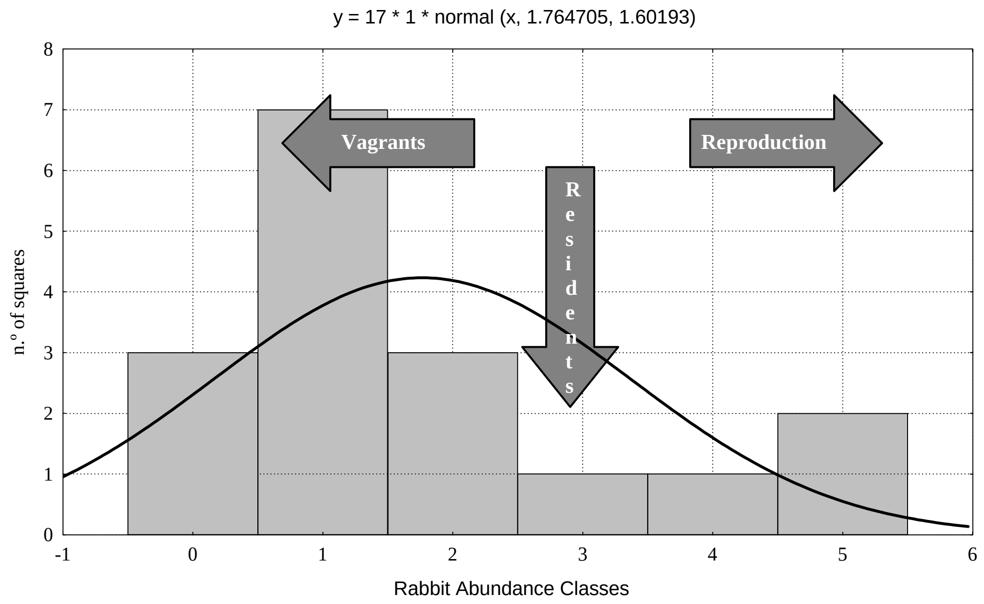

Figure 14 –Rabbit abundance classes histogram for the surveyed 10x10 km UTM squares of North Guadiana. Arrows indicate the theoretical lynx social class that could be present in each class.

Sign search

This area, composed by a total of 17 10x10 km UTM squares, was surveyed from January 2002 to May 2003, in three sampling stages (January-February 2002; August 2002, February-May 2003).A global effort 215.52 man-hours of systematic sampling was applied (Table 4) (average 39.90 ± 3,09 26 man-hours per surveyed square) and 31 potential feline scats were collected, being 18 of these (70%) submitted to DNA analyses (average 1.06 scats per square, SE = 1.34, *n* = 17, range 0-6) (Figure 13). None of the collected faecal samples was identified as being of lynx origin.

◄**Photograph 10** – Typical vegetation of the Adiça-Ficalhos complex.

Camera trapping

Camera placing and effort

Trapping polygon and buffer area measured a total of 50.741 km^2, and it was composed of 36 camera trapping stations (Figure 14), that were placed from 17 of April till 12 of June 2003, comprising a total of 758 cameras-days. Medium distance between cameras averaged 560 m and we obtained a density of 0.70 cameras/km^2.

Carnivore detections

Five carnivores species were photographed in Adiça study area, with a clear dominance of red fox (Table 6). This canid visit a total of 17 stations and we estimated, by the analysis of morphological features, that, at least, 11 animals were present in the sampled area, which corresponds to a minimum density of one animal per 3.9 km^2. We also detected reproduction, since we photograph several cubs in three distinct stations. Genets and mongooses, small carnivores that are usually abundant in Mediterranean scrubland areas, were also photographed in considerable high rates (Table 6, Annex I).

Despite habitat parameters were quite adequate for lynx presence, no photographs of this species were taken (Table 6).

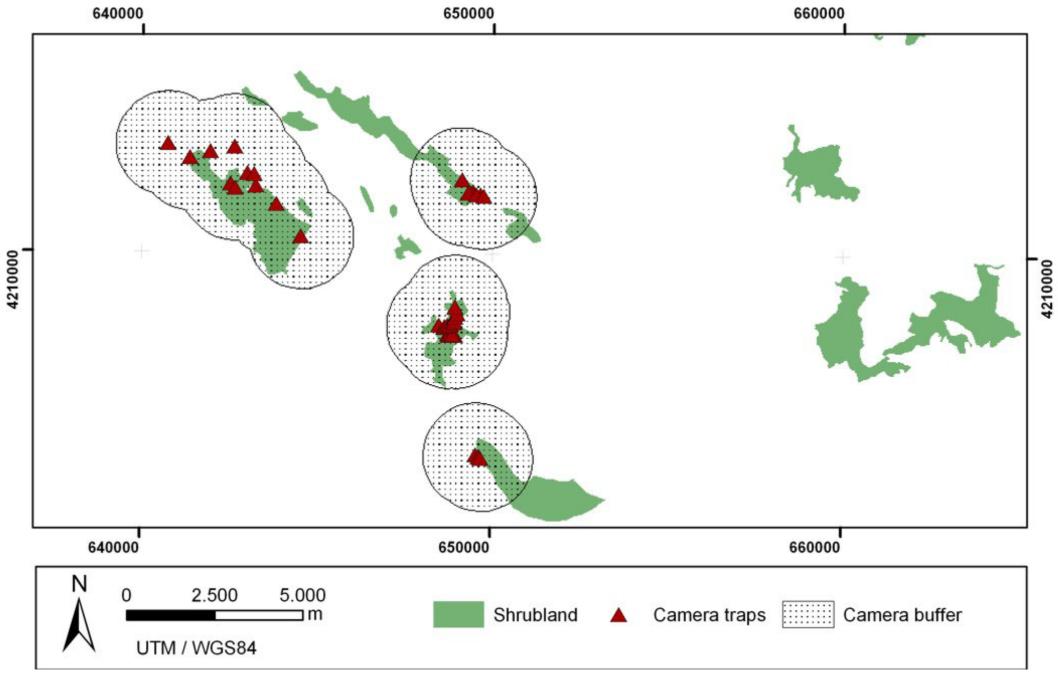

Figure 15- Trapping polygon and buffer area for the camera-trapping lynx survey in North-Guadiana.

Lynx detection probability

For the set of cameras placed on this area the probability of detecting one resident animal was considerably high ($p>0.99$), for the all set of plotted scenarios (smallest and largest home-range and daily travelled distances).

Table 6: Camera trapping data for the geographic area of Adiça (North Guadiana valley) Ns – number of positive stations. Nd/100 d-c – number of detections per 100 camera-days. RAI-relative abundance index.

	Ns	%	Nd/100 d-c	RAI
Stone marten	1	2.78	0.13	0.13
Badger	1	2.78	0.13	0.13
Iberian lynx	**0**	**0.00**	**0.00**	**0.00**
Red fox	17	47.22	2.24	38.13
Genet	8	22.22	1.06	8.44
Egyptian mongoose	6	16.67	0.79	4.74
Total	**23**	**63.89**	**3.03**	

3.2.4 South Guadiana

Area description

▲ **Photograph 11** – Landscape aspect of South-Guadiana.

This study area, that includes the entire range of Vale do Guadiana Natural Park, (Figure 16), is located between 37º 53´48´´ N - 37º 11´76´´ N and 7º 18´50´´ W - 8º 09´43´´ W and encompass a total of 28 10 x 10km UTM squares. The natural vegetation is the typical scrubland of a dry thermo-Mediterranean environment. The *Myrto communis* - *Querco rotundifoliae* S. series is dominant; however, the landscape can be predominated by sub-serial stages: such as: 1) *Genisto hirsutae – Cistetum ladaniferi cistetosum monspeliensis*; 2) *Asparago albi – Rhamnetum oleoidis*.

Some of the peculiarities of this area includes the presence of *Phlomido purpureae – Juniperetum turbinatae*, *Genistetum polyanthi* and *Phlomido purpurae – Cistetum albidi* associations. There are still dry meadows of *Centauro ornatae – Festucetum duriotaganae* in the rocky riverbed of the Guadiana River and main tributaries. However, natural vegetation is pretty much fragmentised. The patches of scrubland are separated by cereal fields, pasturelands and forestations of *Pinus pinea* L. and *Quercus ilex* L. subsp *ballota*. The natural vegetation patches occur mainly in the Guadiana riverbed and neighbouring valleys and in the main elevations (Photograph 11).

Rabbit density and distribution

We observed an average rabbit abundance index (RI) of 38.94 (SE= 8.42, *n* = 27, range 1-575) (Figure 7). A total of 3 596 rabbits latrines was mapped, corresponding to an average of 131.92 latrines per square (SE = 97.33, *n* = 27, range 0-1071). In this area, rabbits were more abundant in Mediterranean scrubland than in pine plantations and other areas. We identified four potential squares were rabbit density could allow lynx reproduction (Figure 17). This areas, located near Mértola (Serra de São Barão, Alcaria Ruiva and Serra Branca) had the highest rabbit densities in all study area and also presented suitable undestory vegetative cover needed for successfully capturing prey and breeding.

In open habitats, rabbit density is lower or the species is even absent. In many places shrub vegetation was totally removed and sowed with grasses for cattle grazing. As a result of this habitat transformation this habitat held many fewer rabbit than Mediterranean scrubland.

Sign search

This area was surveyed from January 2002 to May 2003, in three sampling stages (January-February 2002; April-August 2002, February-May 2003).A global effort 678.30 man-hours of systematic sampling was applied (Table 4) (average 39.90 ± 3,09 26 man-hours per surveyed square) and 136 potential feline scats were collect, being 92 of these (67%) submitted to DNA analyses (average 2.67 scats per square, SE = 1.34, *n* = 17, range 0-12) (Figure 16). No positive lynx amplifications were achieved for a DNA extraction level of 98% of the scats.

Camera trapping

Camera placing and effort

Cameras were maintained on the field since July 2002 till November 2003, comprising a total of 3424 camera-days for a total of 86 camera-stations in 10 trapping sites (Alcaria Ruiva, Eira

Queimada, Ribeira de Carreias, Bicho Aviado, Serra Branca, Corte Pequena, Cela, Ribeira do Vascão, Picoitos and Vale Covo, Figure 18).

Carnivore detections

No Iberian lynx detection was obtained (Table 7). However, the results reveal that, at least, eight species of terrestrial carnivores are present in the Guadiana Valley Natural Park and surroundings. The detected species were the European wildcat (*Felis silvestris*), the red fox, the stone marten, the badger, the polecat (*Mustela putorius*), the otter (*Lutra lutra*), the genet and the Egyptian mongoose (Table 7).

A relevant aspect of the results is the high photographic rates of wildcats (RAI = 19.43) (Table 7), which is classified as a threatened species in Portugal. The results suggest that a significant population of this feline is present in the central area of PNVG. High RAIs were also obtained for the stone marten and red fox (RAI = 5.80 and 16.93 respectively) (Table 7).

The distribution of these species is not equal for the surveyed area. There seems to be a segregation of species which can be related to habitat characteristics and food availability. The wildcat seems to occupy the areas of more suitable habitat for the Iberian lynx on the central part of the Guadiana Valley Natural Park. These areas present a well developed Mediterranean scrubland cover, high rabbit densities and optimal hunting areas for the feline. The Stone marten is more frequent on areas of lower rabbit abundance and more closed habitat. On the other hand, the red fox occupied almost the entire landscape, even in areas where rabbit was not detected.

All the photographed species seemed to respond properly to the applied attractant, and even marking behaviour was several times recorded for most species.

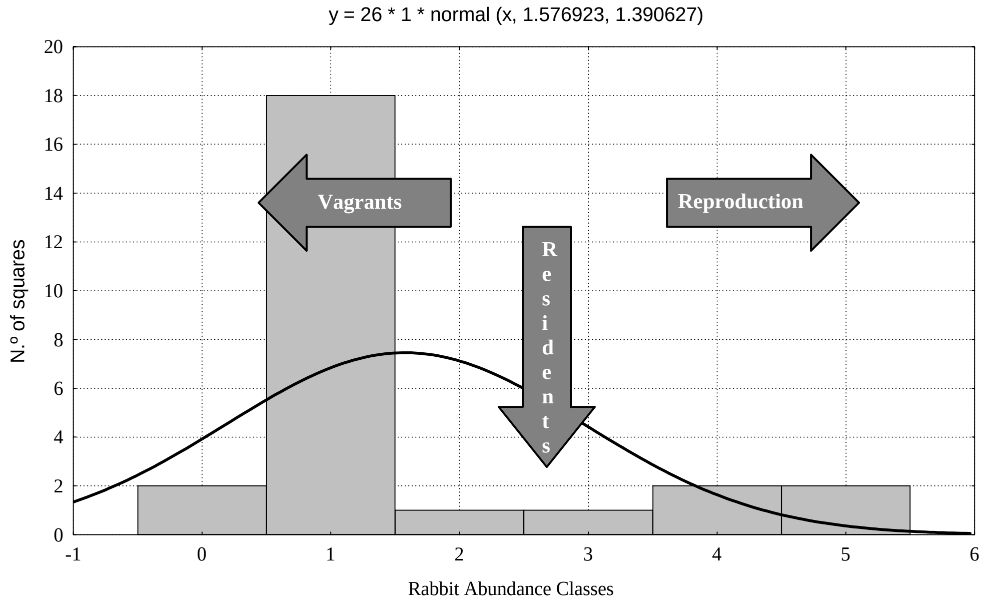

Figure 17 –Rabbit abundance classes histogram for the surveyed 10x10 km UTM squares of South Guadiana. Arrows indicate the theoretical lynx social class that could be present in each class.

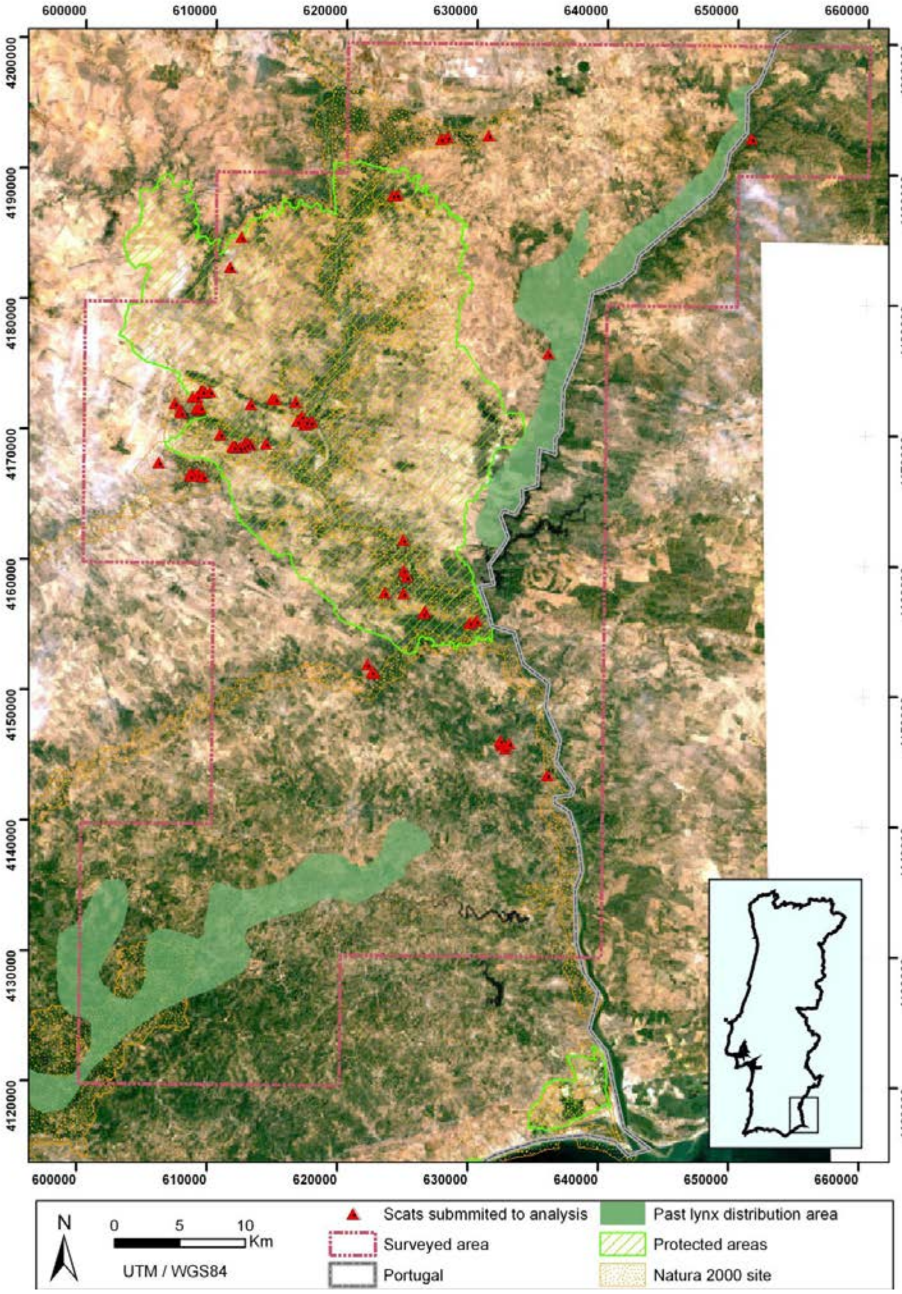

Figure 16- South-Guadiana study area: surveyed area, protected and classified areas, former lynx range (Ceia *at al.*, 1998) and geographic distribution of the potential lynx scats collected for genetic analysis.

Table 7 - Camera trapping data for the geographic area of South Guadiana Ns –number of positive stations. Nd/100 d-c – number of detections per 100 camera-days. RAI- relative abundance index.

	Ns	%	Nd/100 d-c	RAI
Stone marten	18	21	0.85	5.80
Polecat	1	1	0.03	0.01
Otter	1	1	0.03	0.01
Badger	4	5	0.38	6.63
Iberian lynx	**0**	**0**	**0.00**	**0.00**
Wildcat	15	17	0.76	19.43
Red fox	21	24	0.96	16.93
Genet	7	8	0.29	1.78
Egyptian mongoose	13	15	0.50	3.72
Total	**23**	**64**	**0.48**	**-**

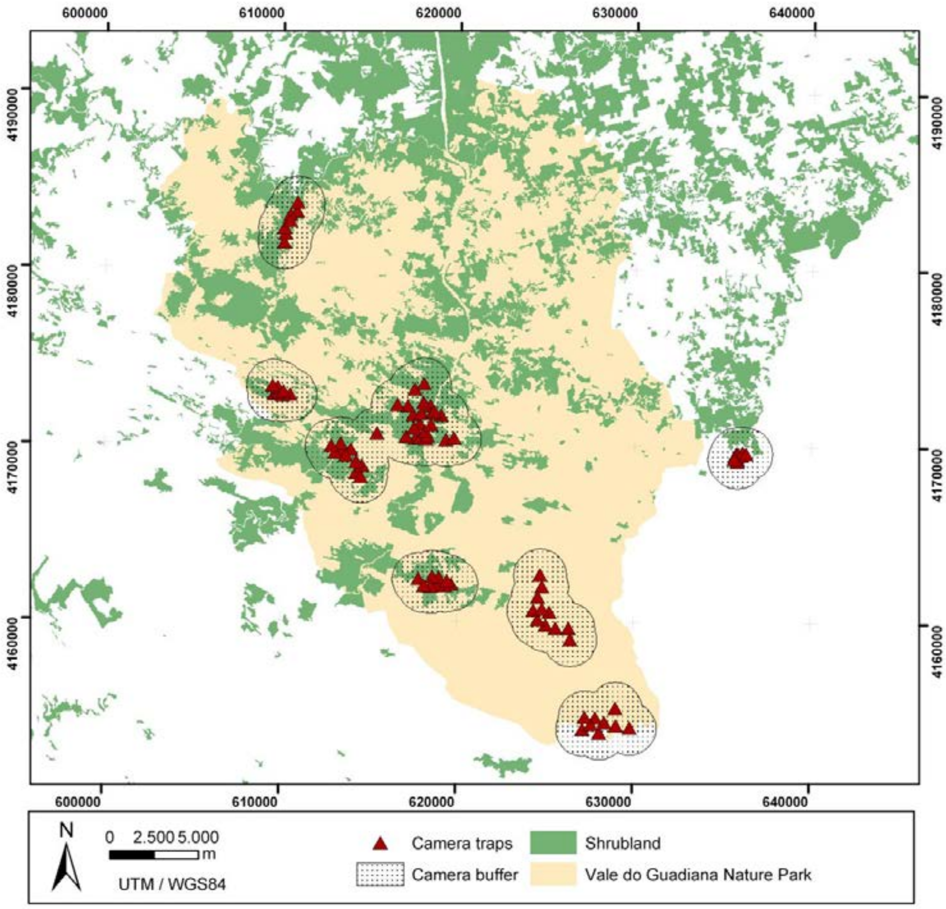

Figure 18- Trapping polygon and buffer area for the camera-trapping lynx survey in South-Guadiana.

Lynx detection probability

As in other areas, the simulations, based on the random walk model, gave us a considerably high probability of photographing, if present, at least one resident lynx ($p>0.99$). This high probability was observed for all the placed set of cameras.

Box trapping

Traps placing and effort

One trapping campaign was conducted in South Guadiana, in an area inside the Natural Park (Figure 19). The campaign was conducted in Alcaria Ruiva, Serra Branca and Serra de S. Barão, and it was carried out from 13 of May to 15 of July 2003. Nineteen box-traps were used for a total trapping effort of 1197night-traps. Traps were distributed over a 123.67 km^2 area, however, once a buffer distance (1.5 km) equivalent to the radius of the minimum lynx home range (10 km2) was added (Ferreras *et al.*, 1999), the total sample area equalled 259.91 km^2.

The area was selected due to the maximum adequacy for lynx presence, in result of the high rabbit densities observed.

Carnivore captures

The trapping campaign resulted in the capture of 34 individuals of five carnivore species. Similar results to the ones obtained for camera-trapping in these areas were achieved. A total of 13 wildcats were captured for a trapping rate of 1.09 animals /100 trap-nights (one wild cat per 92.07 trap-nights). Other carnivores were captured in significant lower rates (Table 8)

Table 8 - Box trapping data for the geographic area of South Guadiana Nc –number of captures. Nd/100 d-c – number of captures per 100 camera-days. RAI- relative abundance index.

	Ns	**%**	**Nd/100 d-c**
Stone marten	6	18	0.50
Iberian lynx	**0**	**0**	**0.00**
European Wildcat	13	38	1.09
Red fox	4	12	0.33
Genet	5	15	0.42
Egyptian mongoose	6	18	0.50
Total	**34**	**100**	**2.84**

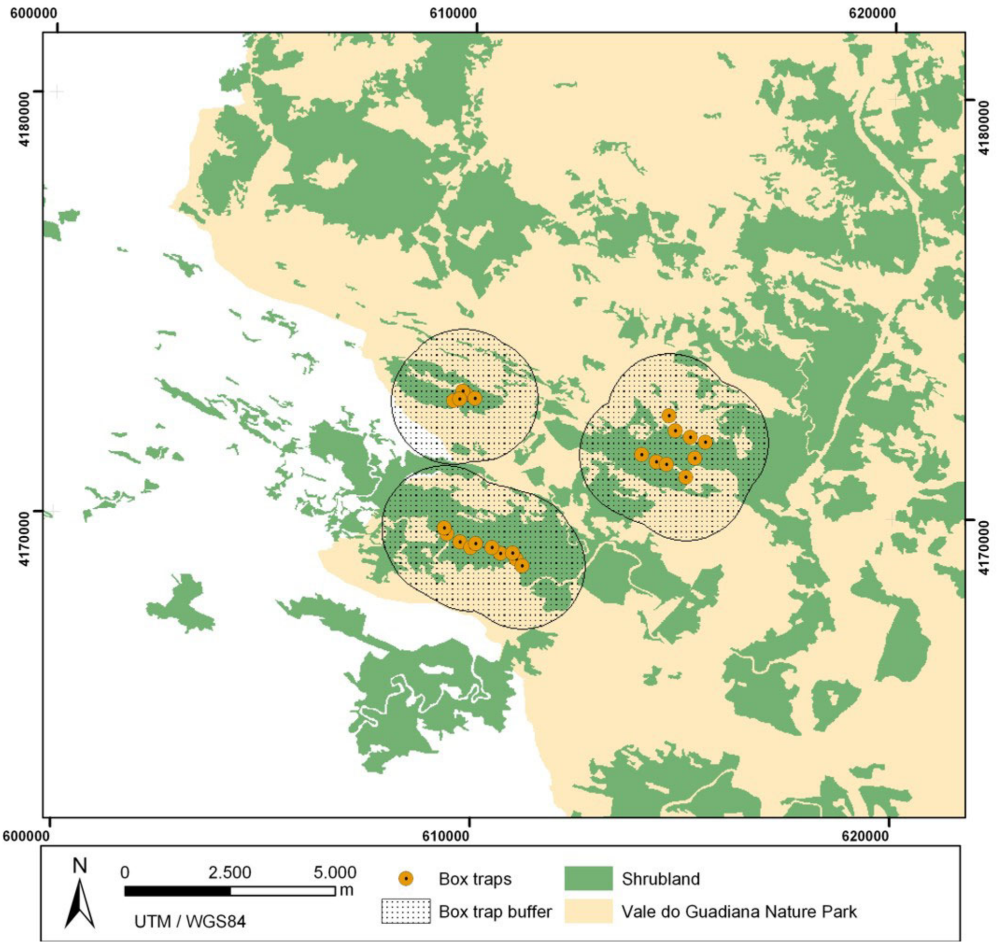

Figure 19- Trapping polygons and buffer areas for the two box-trapping campaigns conducted in South Guadiana

3.2.5 Algarve-Odemira

Area description

This extensive predominantly hilly area is located between 37º 38´36´´ N - 37º 10´71´´ N and 8º 47´91´´ W - 7º 47´33´´ W, spreading from Serra de Grândola southwards to the far edge of the Serra de Monchique/Espinhaço de Cão complex southeastwards to the eastern part of the Serra do Caldeirão and then across the hills of the Mira basin (Figure 20).

▲**Photograph 14** –Landscape overview of Serra de Monchique.

The potential natural vegetation is composed cork-oak tree, and other *Quercus* species (*Q. faginea*, *Q. rotundifolia Q. canariensis* and *Q. pyrenaica*) and an understory cover composed by *Ericaceae*, *Leguminosae* and *Cistaceae* species (Photograph 14) . Currently, this vegetation type is restricted to small and fragmented patches in protected north-facing slopes. In less steep areas, specially where cork exploitation is more intensive, shrub layer is usually removed, resulting in the replacement of the original forest by open cork-oak woodlands with degraded understory and thinner soils.

The abandoned former farming areas gradually evolved to large extensions of *Cistus ladanifer* interspersed with heather patches, which are the dominant landscape feature throughout the area, although they are heavily fragmented at present through clearance for forestry-related purposes. Significant parts of the area are covered by plantation of pine trees (*Pinus pinaster* and *Pinus pinea*) and *Eucalyptus* species.

Rabbit density and distribution

During the current survey, rabbit presence was detected in 32 UTM squares (83%) (Figure 6). Rabbit abundance indexes ranged between 0 to 91 (SE= 25.24, n = 36, average = 20.45). A total of 3014 rabbit latrines was mapped, which corresponds to an average of 2.06 latrines per surveyed km (SE = 2.16, n = 1465.54, range 0-241). We did not observed any high density squares compatible with a staple lynx population with reproduction. Only four squares (11%) had a rabbit abundance compatible with resident lynxes (Figure 21). As in other low density areas, the field workers did not observed either rabbits or warrens. This fact is, clearly, an indicator of the low suitability of this geographic area for lynx.

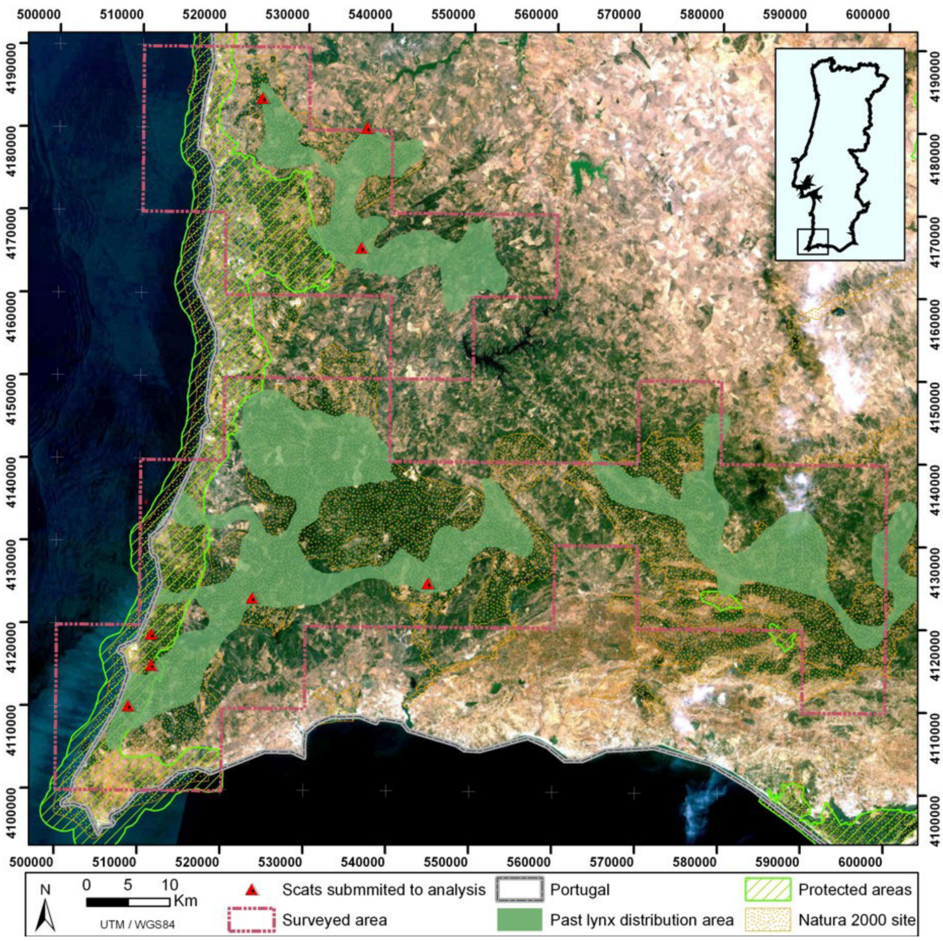

Figure 20- Algarve-Odemira study area: surveyed area, protected and classified areas, former lynx range (Ceia *at al.*, 1998) and geographic distribution of the potential lynx scats collected for genetic analysis.

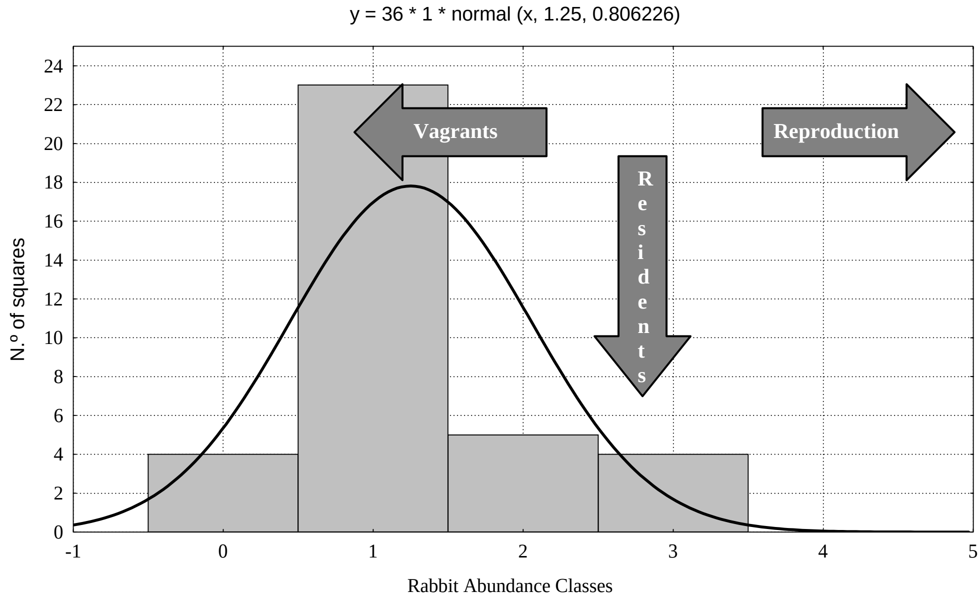

Figure 21 –Rabbit abundance classes histogram for the surveyed 10x10 km UTM squares of Algarve-Odemira. Arrows indicate the theoretical lynx social class that could be present in each class.

Sign search

The Algarve-Odemira lynx range was submitted to intensive and continuous survey from 1994 to 2002 (Castro, 2003). Composed by a total of 36 10x10 km UTM squares, during the present survey, this area was submitted to field work during January and February 2002, in a global effort of 586 man-hours (Table 4). Our survey resulted in the collection of 35 potential feline scats (0.06 scats/man-hour), being 18 of these (51 %) submitted to DNA analyses (average 0.51 scats per square, SE = 2.01, *n* = 36, range 0-4). No positive lynx amplifications were obtained.

3.1.2.4 Sado valley

Area description

This area, located between 38º 28´40´´ N - 38º 12´40´´ N and 8º 38´06´´ W - 8º 10´50´´ W (Cabrela e Ermida do Sado) is highly heterogeneous in terms of habitat patterns (Figure 22). Slope is extremely plain, being dominated by the Sado river. Rifted areas occur in the mountains of Monfurado and Grândola. Along the Sado river vegetation is dominated by highly open agriculture fields and in the more declivous areas appears thick vegetation of *Cistus ladanifer*, *Halimium* sp. and *Erica sp.* intercepted by extensive industrial plantations of *Eucalypus* spp. and pine tree species (Photograph 15).

Photograph 15 –Spontaneous vegetation of Sado valley.▲

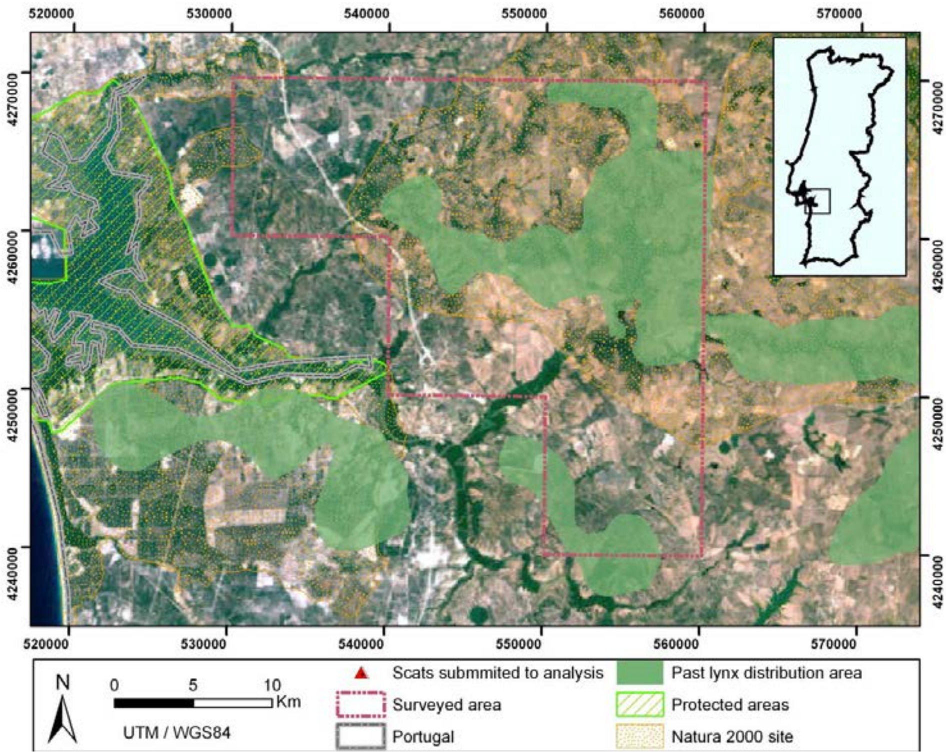

Figure 22- Sado valley study area: surveyed area, protected and classified areas and former lynx range (Ceia *at al.*, 1998).

Sign search

For a total of six 10x10 km UTM squares, we applied a global prospection effort of 56.39 man-hours, corresponding to 43.40 km searched (Table 4). No potential scats were found.

Rabbit density and distribution

Rabbit presence was detected in four of the surveyed squares (67%) (Figure 23). It was possible to observed that this lagomorph was patchily distributed, with relative abundance in very localized parts, whereas in other parts it is totally absent (Figure 6). We mapped a total of 73 rabbit latrines, corresponding to 1.68 per surveyed km (SE=1.61, n = 43.40, range 0-21), observing an average abundance index per square of 3.76 (SE = 3.48, n = 6, range 0.00-18.92)(Figure 7). From the collected data it was possible to observe that the densities are not compatible with the presence of resident lynxes (Figure 23).

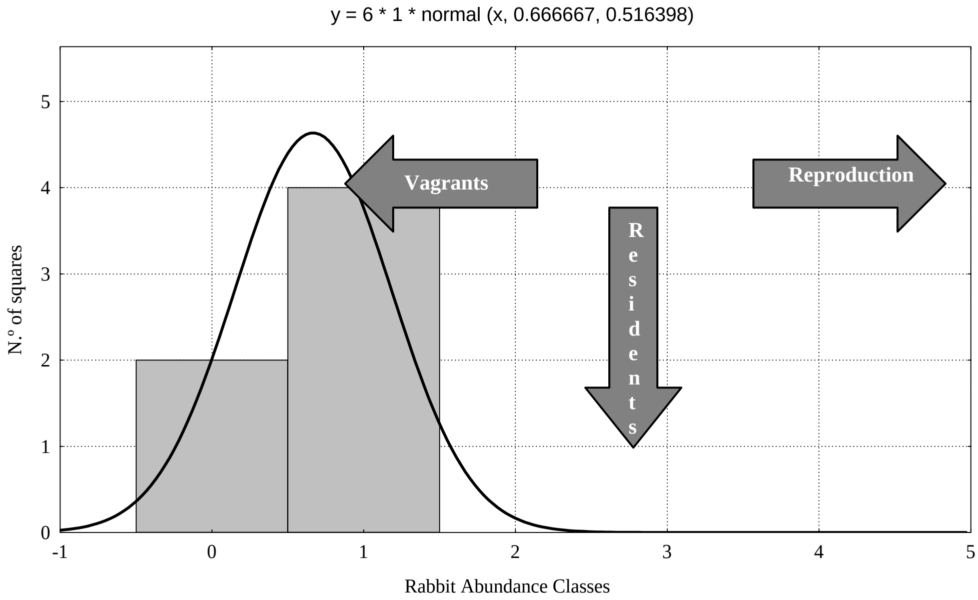

Figure 23 –Rabbit abundance classes histogram for the surveyed 10x10 km UTM squares of Sado valley. Arrows indicate the theoretical lynx social class that could be present in each class.

4. DISCUSSION

4.1 Past and current situation in distinct nuclei

4.1.1 Malcata-Tejo-Nisa-S.Mamede (Central western mountains)

4.1.1.1 Malcata

Malcata has been pointed out as a lynx occurrence area since the 19th century (Lopes, 1899). The 1998 census (Ceia *et al*., 1998) classified this territory with high importance for lynx conservation, being estimated a Portuguese sub-population of 7 to 9 animals, which occupied approximately 450 km^2 (medium density of 1,8 lynxes/100 km^2) (Figures 1 and 5). According to Delibes *et al.* (2000) this sub-population was integrated in the Gata-Malcata-San Pedro-S. Mamede meta-population, composed by 75 to 95 individuals distributed throughout 2 050 km^2 (Figure 1). Bessa-Gomes (2000), in her viability analysis of lynx Portuguese populations, stated that, although Malcata had low lynx effectives, this population could persist as a sink of nearest Spanish nucleus, even considering the most pessimists scenarios.

Despite the relative optimistically perspective pointed above, several studies, conducted since the mid-1990s, described an incompatible situation with the previous described data (Sarmento & Cruz, 1998; Eira, 1999; Sarmento *el al.*, 2001). The species is not detected, with reliable methods, since 1997 and in Spain the most recent data describes a possible extinction of historical lynx nucleus of Sierra da Gata and Hurdes (Guzmán *et al.*, 2002) (Figure 2).

4.1.1.2 Tejo-Erges

The southern part of this territory (Tejo, Ponsul and Erges rivers), was defined by Ceia *et al.*(1998) as a probable ecological corridor between the populations of S. Pedro-S. Mamede and Gata-Malcata (Figures 1 and 5). This conclusion was supported by the report of three lynx sightings, between 1987 and 1993, that, according to the authors, could signified dispersion between the nuclei of Cilleros-Malcata or Cedillo-Malcata

The lynx nucleus of Cedillo and Cilleros, classified with regular presence by Rodriguez & Delibes (1990), is probably extinct (Guzmán *et al.*,2002) (Figure 2). Although in recent years a considerably high camera-trapping effort was conducted in these areas, no lynx detections were achieved (Guzmán *et al,* 2002).

Considering the historical importance of the Malcata nucleus for lynx conservation in the country, this area was submitted, during the present study, to an intensive surveying effort. A significant sample of potential lynx scats was submitted to DNA analyses and camera-trapping efforts applied gave us a 95% probability of detecting, at least, one resident animal. Although the negative results can not entirely support the conclusion of the species extinction an extremely negative perspective is pointed out.

4.1.1.3 Nisa

Previous studies classified the Nisa geographic area with lynx regular presence (Ceia *et al.*, 1998), being calculated a population nucleus of 3-4 adult individuals, distributed throughout 200 km^2 (medium density – 1.75 lynxes/100 km^2) (Figures 1 and 10). The study referred above also pointed out the possibility of a recent lynx recolonization, in this area, carried out by dispersing individuals. This conclusion was supported by a lack of observational data since 1957 to 1970.

During the present study, lynx presence was not detected and we verified low habitat suitability patterns for the species. Mediterranean scrubland areas are scarce and fragmented, and rabbit is probably absent from 40% of the area, and, when present, estimated density is extremely low (<0.5 rabbits/hectare).

In the nearby Spanish lynx historical range (Cedillo), a similar situation was verified by Guzmán *et al.* (2002). Rabbit was absent from 42% of the territory, and in 33% was present in low density. Guzmán *et al.* (2002) conducted in this area a camera trapping effort of 978 camera-days and no lynx photographs were taken.

4.1.1.4 S. Mamede

S. Mamede mountains, located south from Nisa, were referred by Ceia *et al.* (1998) has an area of undetermined status for lynx (Figures 1 and 10). In our study, after a total searching effort of 170 man-hours (Table 4), our teams did not collect any lynx positive scat and, as in Nisa, it was found an unsuitable landscape for this feline.

Recent abundant reports of lynxes from the Campo Maior Special Protection Zone (ZPE) are highly likely to be erroneous, since the small amount of Mediterranean scrubland habitat present is too scarce, fragmented and surrounded by intensive agricultural cover.

Serra de Ossa, a 45 km^2 Mediterranean scrubland area, located South-west from S. Mamede, suffered, according to Ceia *et al.* (1998) a lynx recolonization process, by vagrants from Nisa and Adiça. However, probably due to low rabbit density, it was and impossible to obtain any lynx data during our survey, and evidences suggested that it is even possible the absence of the species.

4.1.1.5 Metapopulation Gata-Malcata-S.Pedro-S.Mamede

When Delibes *et al.* (2000) defined the meta-population of Gata-Malcata-S. Pedro-S. Mamede, they estimated the total amount of Iberian lynx habitat at 2050 km^2 with a population of 75-95 individuals (assuming a mean density of 1 animal per 21-27 km^2) (Figure 1).

Considering that there are fewer prey resources compared with the past, which causes lynxes to wander in larger range in search of food, coupled with low numbers of lynxes, it can lead to the disappearance of evidences. With the human disturbances, fragmented habitats and low prey density, lynxes could no longer keep their relatively stable territories and reproduction could be compromised and local extinction could be an hypothesis. For this meta-population, there are no reliable evidences in the last five years (Table 9).

4.1.2 Guadiana Valley

Ceia et al. (1998) estimated the total population at about 4-7 lynxes within an occupied range of some 270 km^2 (based on an average of one cat per 67 km^2) (Figure 1). Their range map shows a highly fragmented range including the Contenda-Barrancos nucleus (irregular presence), the Adiça nucleus (regular presence) and two areas of undetermined status: Alcarreche-Guadelim and International Chança.

4.1.2.1 Contenda-Barrancos

According to Palma (1980), Iberian lynxes once occupied most of the large Mediterranean scrubland ranges on the Contenda-Barrancos border, and presently there are evidences that support this statement, particularly the presence of a significant amount of pelts and stuffed animals. More recently, Ceia *et al.* (1998) estimated an extirpated population of 2 to 3 animals, occupying an area of 170 km^2 (Figures 1 and 13).

Table 9: Comparison between past and present situation of Iberian lynx in the Central western mountains

Population Portugal [; SpainE	**Past situation (# lynxes . occupied area) Ceia *et al.*(1998) [; Rodríguez & Delibes (1990)/Delibes *et al.*(2000) E**	**Present situation Current study 6; Guzmán *et al.* (2002) 4**
Malcata [	7-9 (450 km^2) [	Not detected 6
Gata-Cilleros E	24-39 (760 km^2) E	Not detected 4
Tejo-Erges [	1? (130 km^2) [	Not detected 6
Nisa [	3-4 (200 km^2) [	Not detected 6
Cedillo E	5-7 (100 km^2) E	Not detected 4
S. Mamede [	1 (185 km^2) [	Not detected 6
San Pedro E	34 (410 km^2) E	Not detected 4
Total	**75-95 (2050 km^2)** E	**Not detected**

4.1.2.2 Adiça

This area, contiguous to Contenda-Barrancos, presents, currently, high habitat suitability for lynx, particularly high rabbit density that could allow lynx reproduction. Ceia *et al.* (1998) judged there were about 2-3 lynxes in the 100 km^2 of suitable habitat in Adiça (Figures 1 and 13) and a lynx positive scat was found in this area in late 2001 (Santos-Reis, 2003).

Although, during our survey this area was intensively prospected and camera-trapped, with no positive results, a few cats may persist in the Spanish bordering area of Rosal de la Frontera and transients could be occasionally present in Adiça. Field work will continue in order to address properly this question.

4.1.2.3 Mértola

Although, this large Mediterranean scrubland territory was not included as a lynx area in previous surveys (Ceia *et al.*, 1998), we estimated a potential Iberian lynx range that totals as much as 10 78 km2. The GIS-generated estimate provided an high probability of the existence of a viable lynx population in this area. That was one of the reasons for targeting most of our surveying effort to this territory. The possibility of dispersing animals from the Doñana lynx population reaching this area was also in the base of our strategy.

According to the study of Palomares *et al.* (1999) there is a significant connectivity between the Portuguese-Andaluzian border and Doñana, although a few problematic barriers may occur, particularly the Huela-Sevilla highway and the Tinto river.

Palomares *et al.* (1999) stated that several habitat types are suitable for lynx dispersion, namely: 1) Mediterranean scrubland, 2) eucalyptus plantations and 3) pine tree plantations. Other sorts of habitat such as open areas with no vegetation, crop fields or olive trees landscapes, could constitute a barrier depending on its extension. However, in this last case, it was possible to verify that areas with extensions less than 5 km, between suitable patches could be used by lynxes, and, in one case, an animal crossed a theoretical barrier with, approximately 16 km of extension. Based on this information Palomares *et al.* (1999) gave the following definition for a lynx dispersing habitat:

1- Areas covered by Mediterranean scrubland or by industrial plantations are suitable for lynx dispersion;
2- Areas of open habitat of less than 5 km of extension, between suitable areas, could be used for dispersion;
3- Areas between 5 to 16 km of extension, could be crossed, although with difficulty and potential risks;
4- Areas with more than 16 km of extension are considered impenetrable barriers.

In yearly 2003, a dispersing female was run over by a car after crossing the barriers of the Huelva-Seville highway and the Tinto river, at a distance less than 40 km from the border (Pereira & Guzmán, *per. com.*). Analysing this event and the Palomares *et al.*(1999) lynx corridor definition it becomes more likely our hypothesis that the frontier between Portugal and Andalusia could be the only area in the country with the possibility of having lynxes, although local historical populations are in the brink of extinction (Table 10).

Table 10: Comparison between past and present situation of Iberian lynx in the Guadiana valley and Eastern Sierra Morena.

Population **Portugal [; Spain**E	**Past situation (# lynxes . occupied area)** **Ceia *et al.*(1998) [; Rodríguez & Delibes (1990)/Delibes *et al.*(2000)** E	**Present situation** **Current study** 6**; Guzmán *et al.* (2002)** 4
Adiça [	2-3 (100 km^2) [	Not detected 6
Aroche-Cumbres Mayores- Rosal E	14 (121 km^2) E	Not detected 4
Contenda-Barrancos [	2-3 (170 km^2) [	Not detected 6
Alcarreche-Guadelim [	1? (135 km^2) [	Not detected 6
Chança Internacional [	? (80 km^2) [	Not detected 6
Mértola[	Not refered	Not detected 6
Andévalo E	21-23 (472 km^2) E	Not detected 4
Total	**40-45 (1078 km^2)** E	**Not detected**

4.1.3 Algarve-Odemira-Sado Valley

4.1.3.1 Algarve-Odemira

Ceia *et al.* (1998) estimated the total amount of Iberian lynx habitat in Algarve-Odemira at 935 km^2 with a population of 19 to 23 individuals, divided by three sub-nuclei (Odemira, Monchique and Caldeirão) (Figures 1 and 20). Mean density was computed at as much as one animal per 45 km^2, making this population, potentially at least, the most important in the country with as much as 40% of all Iberian lynx range.

According to Ceia *et al.* (1998) and Palma (1994) lynx reproduced in both regions (Algarve and Odemira), but were isolated, from other populations, at least, from the last 50 years. Palma (1994) referred the sighting of melanic animals as a preliminary evidence of genetic depression, although a recent study on the viability of lynx populations in Portugal (Bessa-Gomes, 2000), stated that this population was viable even in absence of emigration.

Field work, carried out in this area since early 1990-s failed to produce any authentic lynx existence proofs (direct proofs or positive scats) and our survey was not an exception. In total, from 1994 2865 man-hours and 2954 camera-days were applied and evidences were not obtained. This gives us a strong possibility that past generated estimates provided by Ceia *et al.* (1998) and Palma (1994) were probably extremely optimistical and except from observational data there is virtually no information.

4.1.3.2 Sado Valley

This area was considered in the mid XX th century as an important area for lynx, but in recent decades degenerative process of habitat destruction and prey reduction reduce considerably its importance (Ceia *et al.*, 1998). Ceia *et al.* (1998) judged there were about 6-8 lynxes in 340 km^2 of suitable habitat in the Sado Valley (Santa Susana, Azinheira dos Barros and Comporta) (Figures 1 and 22). As for the Algarve-Odemira range, no consistent lynx presence proofs were obtained after almost ten years of field work and there is a strong possibility of an absence of the species.

The lynx historical meta-population of Algarve-Odemira-Sado valley, that constituted the western range of the species (Delibes *et al.*, 2000), is presently in a situation that could be in the verge of extinction (Table 11). No reliable data is obtained for at least a decade and rabbit density clearly does not allow reproduction, since it requires good-quality habitats.

Table 11. Comparison between past and present situation of Iberian lynx in the Meta-population of Algarve-Odemira-Sado Valley

Population	**Past situation (# lynxes . occupied area) Ceia *et al.*(1998)**	**Present situation Current study4**
Santa Suzana	5-6 (225 km^2) [	Not detected 6
Azinheira dos Barros	1 (115 km^2) E	Not detected 4
Comporta	1? (115 km^2) [	Not detected 6
Odemira	5-6 (220 km^2) [	Not detected 6
Monchique	10-12 (395 km^2) [	Not detected 6
Caldeirão	4-5 (320 km^2)	Not detected 6
Total	**40-45 (1078 km^2)** E	**Not detected**

4.2 Global situation of Iberian lynx in Portugal

Historically distributed[1] through most of Portugal, the Iberian lynx is presently in the verge of extinction (Table 12). Intensive rabbit regression and massive habitat destruction are identified as the main causes of decline in recent decades (Rodriguez & Delibes, 2003).

[1] Historical distribution can be defined as the area a species occupied at the time of its maximum expansion.

Since the beginning of the 1990-s, the Iberian lynx is vanishing from the country. In recent years, reliable information is becoming more rare. Since 1994, 278 excrements were submitted to DNA analysis, including 168 from the present study, 104 from Pires & Fernandes (2001) and six from Santos-Reis (2003) and it was only possible to obtain positive results from three. Two were collected by our team in Vale-da-Ursa, in March 1997, in Serra da Malcata and the other one was collected in Adiça in late 2001 (Santos-Reis, 2003).

This scarcity of data allied with low habitat adequacy, in most historical lynx range, points to a catastrophic situation of the species in the country. Lynx conservation requires good-quality habitats where animals can settle and breed, and adequate connectivity between these areas, since the species traditionally exhibits a meta-population structure (Ferreras, 2001; Palomares, 2001). According to Palomares (2001) general characteristics of habitats sustaining reproductive lynx populations should include:

1- Isolated trees
2- Ideally, 40% cover of understorey vegetation (half of which should be tall shrubs);
3- Abundance of rabbits (at least 4.6 rabbits per hectare in the lynx breeding season).

In the Portuguese lynx historical range we can only find significant areas with this sort of environments in the south-eastern part of the country, particularly in the Andalusian border, where we lack on recent evidence of lynx presence.

Although we can not confirm extinction, the scenario is highly pessimistic. No direct evidence is obtained since January 1992, when an adult female was captured for scientific purposes in Serra da Malcata (Castro,1992). This event constitute the last direct contact of scientifics with Iberian lynx in Portugal and marks the acceleration of the species extinction process that increased dramatically in the second half of the 1990-s.

Table 12: Comparison between past and present situation of Iberian lynx in Portugal

Population	**Past situation (# lynxes . occupied area)** **Ceia *et al.*(1998)**	**Present situation** **Current study**
Malcata-Tejo	5-6 (225 km^2) [	Not detected 6
Nisa-S. Mamede	1 (115 km^2) E	Not detected 4
Vale do Guadiana	1? (115 km^2) [	Not detected 6
Odemira-Monchique-Vale do Sado	5-6 (220 km^2) [	Not detected 6
Total	**40-45 (1078 km^2)** E	**Not detected**

4.3 Sighting data vs. direct evidences

We detected a considerable discrepancy between the data collected from interviews (indirect evidences) (Ceia *et al.*, 1998) and the direct evidences for lynx presence that were recorded during the present and past studies (Sarmento & Cruz, 1998, Eira, 1999, Pinto 2001), both in terms of past presence (skins) and present presence (photographs and faeces). A geographic analysis of the distribution of naturalised lynxes, skins and photographs of hunted animals (Photograph 16), obtained since 1950, revealed three major historical nuclei: Sado Valley, Malcata and Contenda-Barrancos (Figure 24, Table 13). It seems that these areas were submitted to a process that conducted lynxes towards a considerable regression since the 1960s. It is undoubtful that lynxes were present in Contenda-Barrancos till the 1980-s and in

Malcata till the 1990-s, but recently their presence is quite dubious. In the Sado basin there are reliable evidences till the early 1960-s, but since then, lynx existence could not be confirmed.

Table 13: Past data of lynx presence from the populations of Malcata, Contenda-Barrancos and Sado valley, respecting pelts and naturalized animals obtained since 1950 to the present.

Historical nucleus	Number of confirmed evidences	Average date	Range
Malcata	12	1963	1952-1992
Contenda-Barrancos	8	1972	1952-1981
Sado valley	7	1951	1950-1960
Total	**27**	**1962 (SE= 14.51)**	**1950-1992**

Sighting data continues to be quite common, even in areas were lynx presence seems to be quite uncertain. Similar situations were reproted by other authors for other endangered cat species (Chapron, 1998; Hayes, 1999; O´Brien & Kinnaird, 1999)

The detected discrepancy could be the result of several factors. It could be due to the fact that field surveys were not applied extensive enough, or it could mean that many of the collected informations are not reliable. In the last five years, we investigated a total of 37 observations, spread throughout the country, and when a proof was attached (photograph, cadaver etc.) in 100% of the cases it was possible to verify that the information was false. There are considerable evidences that some people tend to confuse lynxes with cats (both wild and domestic), dogs and even wild boars. Undoubtedly informants vary greatly in both their knowledge and their reliability.

Finally, we should take into account that the discrepancy between indirect and direct evidences could be due to recent extinction of the species in a given area. It could be that Iberian lynxes were present in these areas during the lifetimes of the observers, but are no longer there. In fact, even when a direct evidence in the form of the skin is found, we can not confirm the species presence.

It seems quite certain that surveys based on personal interviews tend to generate fictional scenarios that can lead to dangerous conclusions. When we assume that a species status is much more optimistical than it really is, bold management actions, such as creating a genetic reserve of captive animals, are systematically delayed and, in ultimate case, can lead to the species extinction. Society tends to neglect a species conservation until it reaches critical effectives and only when extinction is imminent proper attention is given and recovery plans are carried out.

The dramatic situation that we face in Portugal is, to a great extent, a result of a distorted perspective that was given, during the last decade, of lynx numbers in the country. The fact that we assume that we had, at least, a viable population with reproduction, avoided the decision of capturing animals for a captive breeding programme. Only in late 2001 it was assumed that capturing free-ranging animals would be the proper form to prevent the species extinction. Although a significant effort was putted in this operations, all the attemptions failed.

Over viewing the facts pointed above is clear that, in the future, the following lesson should be taken into account:

- In a critically endangered species conservation the decision-making process is based on the information of its status. Rigorous data is the base-line tool for a correct, time-effective management intervention and so rigorous and proper developed methods should be employed in order to prevent mistakes.

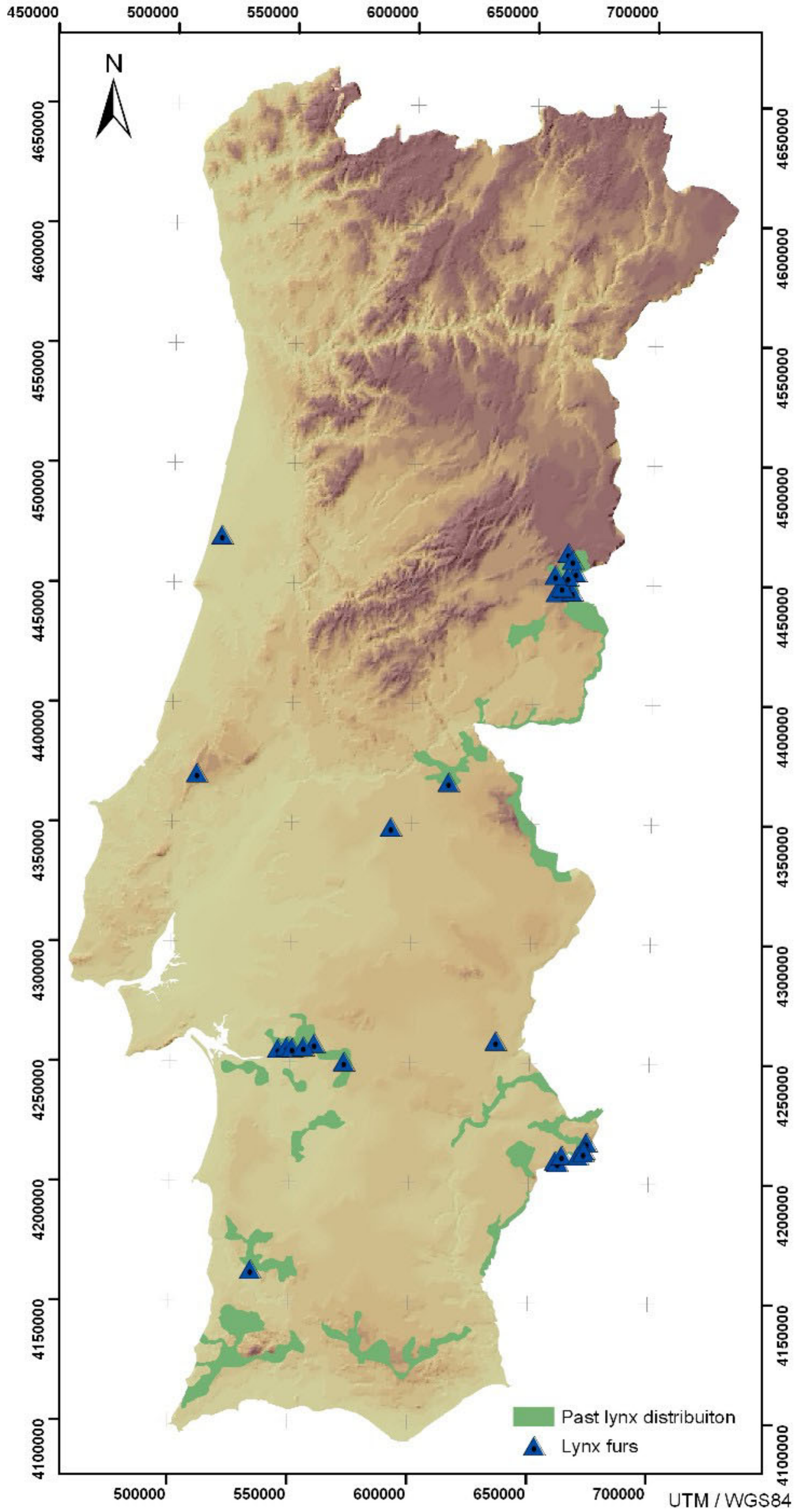

Figure 23- Geographic distribution of lynx pelts and naturalized specimens resulted from shoots and road kills, since 1950 to the present.

4.4 Carnivores and lynx

Another important fact, that should be taken into account, is the specific composition of the carnivore community in the camera trapped areas. This areas, that were chosen for their maximum probability of lynx presence, presented a density of carnivore species which, according to most studies, is incompatible with resident lynxes (Raú. 1988; Palomares *et al.*, 1998).

Our photographic rates for species that are directly influenced by lynx density (foxes, wildcats and mongooses) indicate that lynx presence in those areas could be extremely doubtful. According to Palomares *et al.* (1998) Egyptian mongooses suffer from the negative effects of lynx. It is not rare for mongooses and foxes to be killed by lynxes, therefore avoidance of the areas regularly used by lynxes could be a part of the defensive strategy of those carnivore species (Palomares *et al.*, 1998). There is also recent evidences that wildcats are colonizing and reaching high densities in areas that were formerly occupied by lynxes (N. Guzmán and P. Pereira, *pers. com.*).

▲**Photograph 16** – Juvenile lynx killed in Vila Verde de Ficalho (Contenda-Barrancos lynx occurrence area) in 1969.

We performed a cluster analysis (Ward's method; distance measure Pearson r) using camera trapping data from surveyed lynx areas, both in Portugal (current study and Castro, 2003) and in Spain (Guzmán *et al.*, 2002) (Figure 25). Is clear that, in terms of mammalian carnivore community, is possible to observe five distinct groups (Figure 25):

1- A group consisting of areas, all located in Portugal, where carnivore diversity is low and red fox appears to be the dominant species (Malcata, Adiça, Eira and Algarve);
2- One group made up of the Oriental and Occidental Toledo mountains that exhibited an high mammalian carnivore diversity, with high detection patterns of wildcats, foxes and badgers and no lynx detections;
3- A group composed by Picon (Portugal) and a low lynx density area of Andujár (Spain) (Pearson r distance = 0.07) where red fox dominates but other carnivore species are also common;
4- A group that includes the areas of high and medium lynx density of Andujár, where the lynx appears as dominate species and generalist carnivores exhibit significant low detection patterns;
5- A group composed by a single area located in Mértola were wildcats constitute the most photographed species and other carnivores present low detection rates.

From this analysis is quite obvious that the photographic rates that were observed for carnivore species, in most trapped areas (particularly in Portugal), are an indicator that lynx presence, at least in medium and high density, is extremely unlikely, particularly in areas where carnivore diversity is low and red fox is dominant.

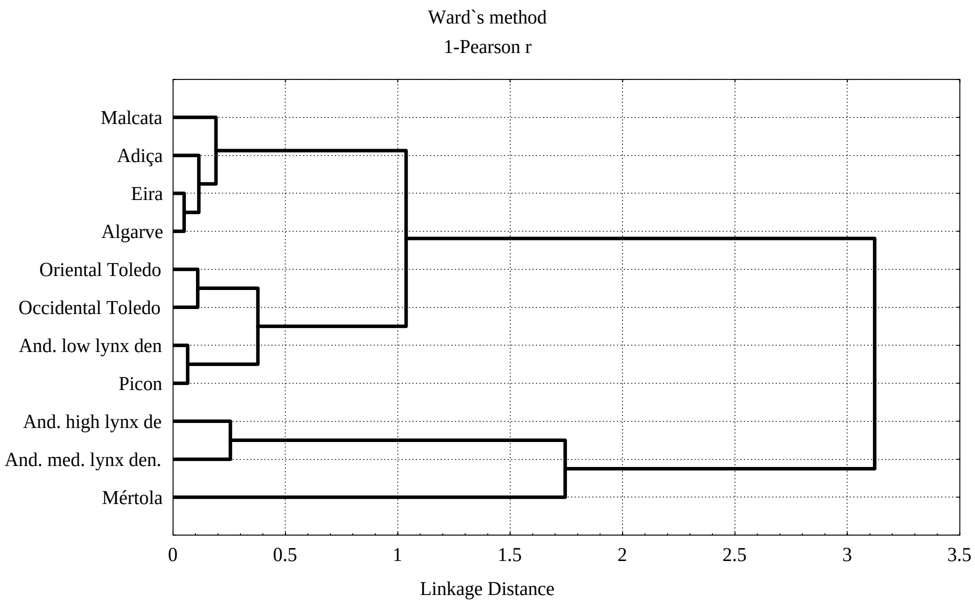

Figure 25 – Graphic representation of the Cluster analysis performed on camera-trapped areas, in Portugal (current study and Castro, 2003) and in Spain (Guzmán *et al.*, 2002), according to mammalian carnivores detections patterns.

5. The future – conservation action plan

5.1 Current situation

The global situation of the Iberian lynx is quite desperate. The two remnant populations of Andujar and Doñana are facing considerable problems related with prey scarcity, inbreeding and diseases. Recent data from Doñana, based on the use of camera-traps, revealed a total of 37 individuals (including young and subadult animals; P. Pereira, pers. com.). The Andujar population is at present estimated in about 100 animals, including 20-25 breeding females. In 2003, 26 cubs were born in this population and only 6 in Doñana.

It seems that the only solution for controlling the extinction process is a proper organized programme of captive breeding and reintroduction. Is a well accepted fact that founders for this programme can only be obtained from the two remnant populations in Andalusia. Presently, there are seven Iberian lynxes in captivity, four females and four males.

The enforcement of most of the proposed measures by IUCN for critical endangered species is being systematically delayed and in Portugal, presently, is not possible to apply any of the listed measures of Table 14, since it is not possible to have access to animals, either captive or free-ranging (Table 15).

Table 14 - Proposed measures by the IUCN for critically endangered species and their aplicationt in Spain and Portugal.

	SPAIN	**PORTUGAL**
Capture of wild animals for captive breeding	Yes	No
Reintroduction of animals in low density areas or extinction areas	No	No
Sperm bank or frozen embryos	No	No
Maintenance of captive animals for breeding or genetic banking	Yes	No
Translocation of individuals or genetic material	No	No

5.2 Conservation Action Plan in Portugal

Becoming aware of the considerable difficulties pointed above, the ICN 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.

Table 15- Levels of conserving biodiversity and their respective status regarding the Iberian lynx in Spain and Portugal.

	SPAIN	PORTUGAL
Wild populations with no human interference	No	No
Wild populations with human management	Yes	No
Captive populations	4 ff; 4 mm	No
Genomic resource bank (reproductive cells)	No	No
Genomic resource bank (somatic cells)	Yes	No

This proposal provides guidance that retains future options, provides management consistent, offers necessary flexibility, in order to achieve the maximum goal of conserving the lynx in Portugal. The plan relies in four guiding principles:

1. **Using the best scientific information available on Iberian lynx**. We used scientific information from research throughout the range of the species, recognizing that exists major differences, both in behaviour and ecology, between the Doñana area (the best studied population) and the rest of the lynx range;

2. **Acting in a conservative way in terms of habitat alterations.** A conservative approach is the best way to conserve the lynx historical range in order to maintain potentiality for future reintroduction;

3. **Consider the habitat requirements of other wildlife species.** An action plan that integrates recommendations for other endangered species is more likely to be successfully implemented;

4. **Develop a useful, proactive action plan to conserve lynx in its historical range, articulated with the Lynx Spanish Conservation Strategy.** The conservation actions proposed in this plan will be focused on suitable areas for lynx or in areas that can be successfully improved for future reintroduction, independently of their conservation status. Actions will act in breeding and dispersal habitats and will be mainly focused in the Portuguese-Spanish border. Therefore the collaboration with Spanish authorities will be a key factor for the plan success.

Approach to the development of conservation measures

The following conservation actions are intended to conserve lynx populations in Portugal, and to reduce or eliminate threat factors. Conservation measures have the goal of provide guiding lines for conservations agents in order to conduct actions that can positively affect lynx and/or to help avoid negative impacts through thoughtful planning of activities. It is expected that plans that incorporate these actions and projects that implement them, will lead to the species conservation across its range.

As previously described, there is a considerable lack of knowledge on the dynamics of the process that conducted lynx populations to the present pre-extinction stage and therefore we don't know the potential effects of several actions upon the species. As a result of this fact, most measures described in the plan are based on the available literature and the document updating will be based on the augment of the information resulting from scientific work and population monitoring.

Aplication level

The proposal of Action Plan will be applied in all the areas located in the lynx historical distribution geographic area[2], that presented suitable characteristics for the species present or landscape features that can be optimised for lynx survival and that can be relevant for the species life-cycle, independently of their protection status (Figure 25).We include in this definition residence, dispersal and reproduction habitats.

Figure 25 – Landscape units for the application of the Iberian lynx Conservation Action Plan.

Conservation measures

Goals and objectives

The goal of this plan is to apply pre-release strategic reintroduction activities in order to make possible, in a long-term, the reintroduction of Iberian lynx, in order to assure the viability of the species, 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.

Ex-situ actions

Ex-situ actions of the plan will be applied as described in the diagramme of Figure 26. The implementation of these measures in Portugal will be completely dependent of the success of the Spanish captive breeding plan and so it is absolutely necessary the establishment of an official agreement between the Iberian states in order for Portugal to have access to captive-born lynxes.

[2] Includes the historical populations of Malcata, S. Mamede, Vale do Guadiana, Sado and Algarve-Odemira (Delibes *et al*., 2000)

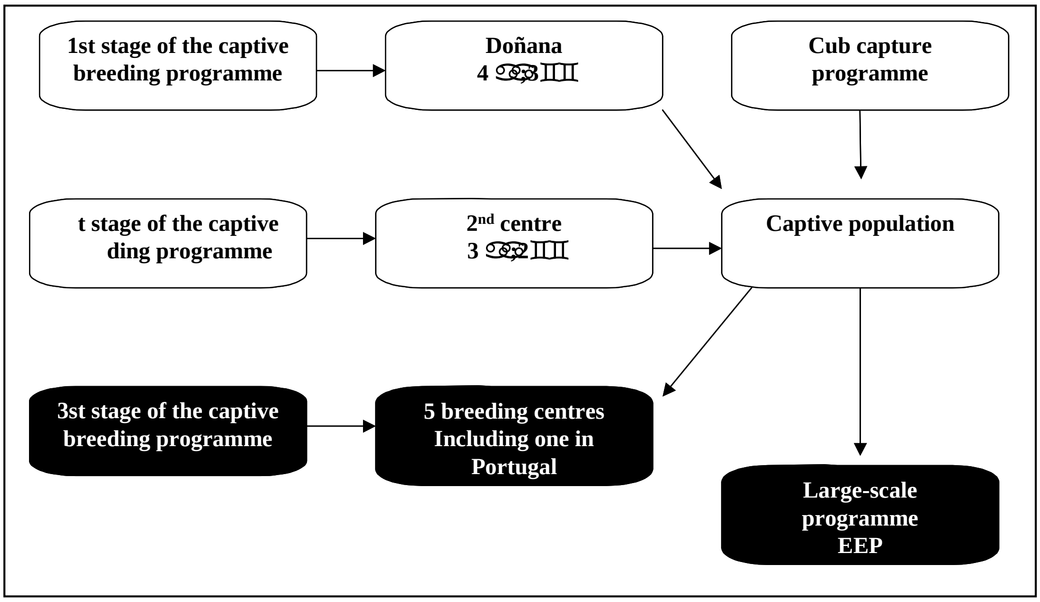

Figure 25 – Descriptive diagramme of the evolution of *ex-situ* actions

Presently, several actions related with captive breeding are being applied in Portugal. These actions include putting together a professional team and construction of facilities for breeding and reintroduction.

In-situ actions

The conservation measures will likely be implemented through three scales of decision-making: home-range level (micro-scale), population level (macro-scale) and ecological corridors, providing broad direction for management activities by establishing goals, objectives and guidelines.

We will establish the following managements units in order to achieve conservation (Figure 26):

1- *Micro.-units for lynx management (MULs):* The micro-units for lynx management are intended to provide the fundamental or smallest scale for evaluation and monitoring of the effects of management actions on lynx habitat.

The MULs should be considered as theoretical home-ranges that should incorporate all the habitat requirements for the Iberian lynx life cycle and should be managed as the species was present even in case of no detection. Therefore, if we choose to apply a reintroduction plan, landscape suitability should be increased or preserved in order to ensure a proper success.

- Guiding lines for establishing MULs[3]

1. The size of MULs should be of 650-1 000 hectares of suitable continuous *habitat* or superior areas in case of fragmented habitat;
2. Rabbit density should vary between 1 individual per hectare, during the low density period, and 4.6 rabbits per hectare during the lynx breeding season;

[3] Conception based on Palomares *et al.* (2001)

3. General characteristics of MULs should include isolated trees, approximately 40% of scrubland cover and pasture land areas;.
4. For each MULs potential lynx habitat should be mapped and reproduction, shelter and hutting areas should be identified;
5. Reproduction habitat should constitute, at least, 10 % of the total area;
6. Any act or activity that could altered this structure should be forbidden;
7. Connectivity between MULs should be maintained.

***2- Macro-units for lynx management* (MALs).** The planification of actions and programmes should not be only focused in the home-range level (MUls). The landscape patterns of significant areas, that correspond to potential populations should be taken into account.
Therefore, several MULs that correspond to theoretical populations will constitute a Macro-unit for lynx management (MALs).

***3- 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 provides for survivorship and movement, is critical in terms of conservation. Although this sorts of habitats usually do not allow reproduction and natality, they are essential for the species life-history requirements.

Project application

In order to achieve the goal of restoring Iberian lynx in Portugal it will be applied a bold plan that will involve inter-agency and international collaboration. The programme will be constitute by several teams that will conduct a multidisciplinary approach (Figure 26). It is necessary to be aware that even with unlimited means and in ideal conditions the future of the Iberian lynx is quite uncertain, both in Portugal and in Spain, and only a professional attitude can prevent the vanishing of this cat species.

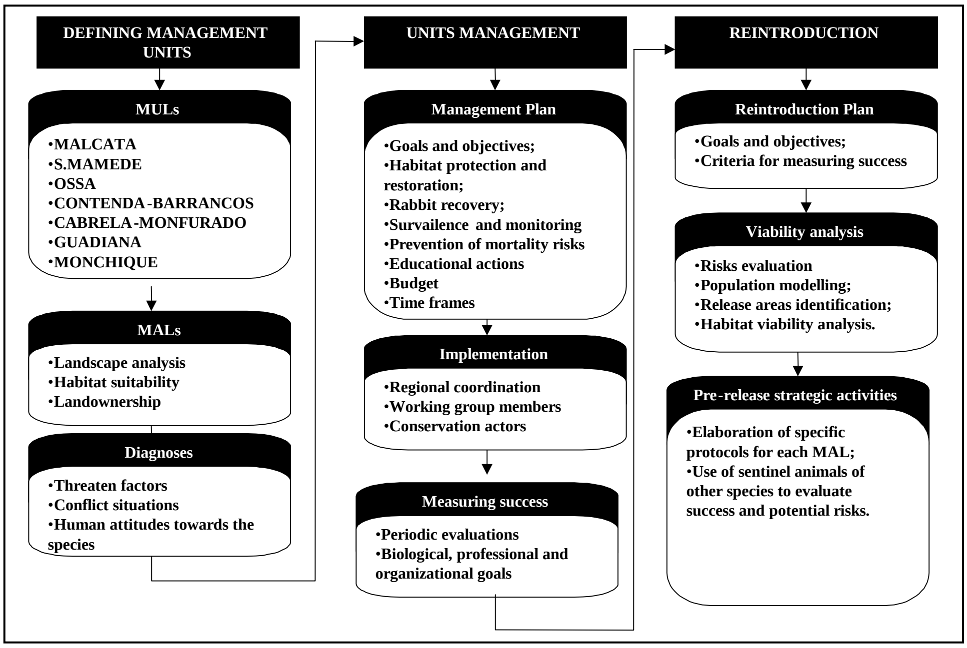

Figure 26 – Phases and application of the Action Plan for Iberian lynx conservation in Portugal.

6. References

Beltrán, J.F., Rice, J.E. & Honeycutt, R.L. (1996) Taxonomic status of the Iberian lynx. *Nature***,** **379**, 407-408.

Bessa-Gomes, C. (2000). Análise exploratória da viabilidade da população portuguesa de lince-ibérico, *Lynx pardinus*. ICN/DHE/ Life programme. Unpublished internal report.

Carbone, C., S. Christie, K. Conforti, T. Coulson, N. Franklin, J. Ginsberg, M. Griffiths, J. Holden, K. Kawanishi, M. Kinnarid, R. Laidlaw, A. Lynam, D. W. Macdonald, D. Martyr, C. McDougal, L. Nath, T. O'Brien, J. Seidensticker, J. L. D. Smith, M. Sunquist, R. Tilson, and W. Wan Shahruddin. (2001). The use of photographic rates to estimate densities of tigers and other cryptic mammals. *Animal Conservation* **4**: 75-79.

Castro, L. & Palma, P. (1996). The current status, distribution and conservation of Iberian lynx in Portugal. *J.Wildl. Res.* **21(1):**179-181.

Castro, L. (1992). *Ecologia e conservação do lince-ibérico (Lynx pardinus) na Serra da Malcata*. Rel. Est. Cien.. FCUL. Unpublished internal report.

Castro, L. (2003). Estudo e monitorização do lince-ibérico no barlvento algarvio. ICN/DHE. Unpublished internal report.

Ceia, H., Castro, L., Fernandes, M. & Abreu, P. (1998). *Lince-ibérico em Portugal. Bases para a sua conservação*. Relatório final do Projecto “Conservação do lince-ibérico”. ICN/LIFE programme. Unpublished internal report.

Chapron, G. (1998). Status and ecological survey of the Andean mountain cat (*Oreailurus jacobita*) in Northern Chile. Institut de Zoologie. Université de Neuchâtel. Unpublished internal report.

Cutler, T.L. and Swann, D.E., 1999. Using remote photography in wildlife ecology: a review. *Wildlife Society Bulletin* **27**: 571-581.

Delibes, M. (1979) Le lynx dans la Péninsule Ibérique: répartition et régression. *Bulletin Mensuel Office Nationale de la Chasse., No. Spe. Sci. Tech. Le Lynx*, 41-46.

Delibes, M., Rodríguez, A & Ferreras, P. (2000). *Action Plan for the conservation of the Iberian lynx (Lynx pardinus) in Europe*. WWF – Mediterranean program.

Eira, C. (1999): *Contribuição para as acções de monitorização dos núcleos de lince-ibérico de Penha-Garcia e de Monfortinho-Idanha-a-Nova*. ICN/RNSM. Unpublished internal report.

Ferreras, P., Beltrán, J.F., Aldama, J.J. & Delibes, M. (1997) Spatial organization and land tenure system of the endangered Iberian lynx (*Lynx pardinus*, Temminck, 1824). *Journal of Zoology*, **243**, 163–189.

Ferreras, P. (2001). Landscape structure and asymmetrical interpatch connectivity in a metapopulation of endangered Iberian lynx. *Biological Conservation.* **100 (2001):** 125-136.

Ferreras, P., Aldama, J.J., Beltrán, J.F. & Delibes, M. (1992). Rates and causes of mortality in a fragmentes population of Iberian lynx (*Felis pardina*). *Biological Conservation*, **61**, 197-202.

Guzman , J.N., García, F. & Garrote, G. (2002). Censo-diagnóstico de las poblaciones de lince-ibérico en España. DGCN. MIMAM. Unpublished internal report.

Hayes, M. (1999). Camera trapping sparks debate on tiger numbers. *Phnom Penh Post*. Number 8/15, July 23-August 5, 1999.

Karanth, K. U. & J. D. Nichols (1998). Estimation of tiger densities in India using photographic captures and recaptures. *Ecology* **79**(8): 2852-2862.

MIMAM (Ministério de Medio Ambiente) (2000). *Propuesta de Plan de Cría en Cautividad del Lince Ibérico*. Dirección General de Conservación de la Naturaleza, Secretaría General de Medio Ambiente, Ministério de Medio Ambiente.

Nowell, C. & Jackson, P. (1996). *Wildcats. Status survey and conservation action plan.* IUCN, Gland Switzerland.

O´Brien, T. & Kinnarid M. (1999). *Survey, assessment and conservation of the Sumatran tigers in Bukit Barisan National Park*. Final report. Save the Tiger Fund. National Fish and Wildlife Foundation.

Oreja, J.A. (1998). Non-natural causes of mortality of the Iberian lynx in the fragmented population of Sierra de Gata (W Spain). *Miscelánia Zoológica,* **21(1):** 31-35.

Palma, L. (1980). Sobre distribuição, ecologia e conservação do lince-ibérico em Portugal. In *Actas I Reunion Iberoamer. Zool. Vert.*, 1977. La Rábida: 569-580.

Palma, L. (1994). *O lince-ibérico Lynx pardina nas serras do Algarve e sudoeste do Alentejo. Avaliação complementar da situação actual.* UCTRA-UAL/SNPRCN. Unpublished internal report.

Palomares, F. (2001). Vegetation structure and prey abundance requirements of the Iberian lynx: implications for the design of reserves and corridors. *Journal of Applied Ecology,* **38**: 9-18.

Palomares, F., Delibes, M., Ferreras, P., Fedriani, J., Calzada, J. & Revilla, E. (2000). Iberian lynx in a Fragmented Landscape: Predispersal, Dispersal, and Postdispersal Habitats. *Conservation Biology* **14(3):**809-818.

Palomares, F., Delibes, M., Godoy, J.A., Piriz, A., Revilla, E., Ruiz, G.,Rivilla, J.C. & Conradi, S. (1999). *Determinacion de la presencia y tamaño poblacional del lince iberico usando técnicas moleculares y un sistema de información geografico*. Consejeria de Medio Ambiente de la Junta de Andalucia. CSIC.

Palomares, F., Ferreras, P., Fedriani, J.M. & Delibes, M. (1996) Spatial relationships between Iberian lynx and other carnivores in an area of south-western Spain. *Journal of Applied Ecology,* 33, 5-13.

Palomares, F., Ferreras, P., Travaini, A. & Delibes, M. (1998) Co-existence between Iberian lynx and Egyptian mongooses. *Journal of Animal Ecology,* 67 (6), 967-978.

Palomares, F., Gaona, P., Ferreras, P. & Delibes, M. (1995). Positive effects on game species of top predators by controlling smaller predator populations. An example with lynx, mongoose and rabbits. *Conservation Biology*, **9**:295-305.

Pinto, B. (2000). *Situação actual do lince-ibérico no sudoeste alentejano e barlavento algarvio*. ICN/DHE. Unpublished internal report.

Pires, A.E. & Fernandes, M. (2000). *Monitorização genética das populações de lince-ibérico.* 2º Relatório de progresso. ICN/DHE. Unpublished internal report.

Raú, J. R., Beltrán, J. & Delibes, M. (1988). Can the increase of red fox density explain the decrease in lynx numbers at Doñana. *Rev. Ecol. (Terre Vie)* **40**: 324-328.

Rodríguez & Delibes (2003). Population fragmentation and extinction in the Iberian lynx. *Biological Conservation*. 109(3): 321-331.

Rodríguez, A & Delibes, M.(1990). *El lince ibérico (Lynx pardina) en España. Distribución y problemas de conservación.* Colección Técnica. ICONA, Madrid.

Sanderson, J, (2002). Tropical ecology, assessment and monitoring (Team initiative). Camera trapping protocol. Centre for Applied Biodiversity. Conservation International. (w.teaminitiative.org/wombatmx/team/application/resources/pdf/cameratrapping_3_12_03.pdf)

Santos-Reis, M. (2003). De novo no rasto do lince-ibérico. www.naturlink.pt. 27/03/2003.

Sarmento P. & Cruz J. (1998). *Ecologia e conservação do lince-ibérico e da comunidade de carnívoros da Serra da Malcata*. ICN/RNSM. Unpublished internal report.

Sarmento, P, Cruz, J., Tarroso, P. & Gonçalves, P. (2001). *Recuperação do habitat e presas do lince-ibérico na Serra da Malcata*. Project Life Habitats. 2º Relatório de Progresso. ICN/RNSM. Unpublished internal report.

Sarmento, P, Cruz, J., Tarroso, P. & Gonçalves, P. (2003). *Recovery of habitats and preys of Lynx pardinus in Serra da Malcata*. Project Life Habitats. ICN/RNSM. Final report.

UICN/MIMAM (1998). Population viability analysis for the Iberian lynx. Cabañeros, Espanha. Maio de 1998.

York, E.C. 1996. *Fisher population dynamics in north-central Massachusetts*. MS thesis, University of Massachusetts, Amherst, MA.

Zielinski , W.J., T.E. Kucera, and R.H. Barrett. 1995. Current distribution of fisher, *Martes pennanti*, in California. *California Fish and Game* **81**:104-112.