



The Status and Distribution of the Iberian Lynx *Felis pardina* (Temminck) in Coto Doñana Area, SW Spain

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ABSTRACT

The distribution and relative abundance of the Iberian lynx Felis pardina at the Doñana National Park and its surroundings (SW Spain) have been determined by tracks and faeces by searching in 5 × 5 km squares. Two density categories distinguish sampling units where lynx reproduction is or is not estimated to occur. Absolute abundance was estimated in two ways by comparing with previous radiotelemetric studies. The population is made up of no more than 50 individuals, divided into two nuclei relatively isolated one from the other.

High relative density mostly coincided with protected areas. Lynx presence positively correlated with shrub cover and rabbit abundance. The lynx population undergoes high unnatural mortality rates. Conservation proposals are noted.

INTRODUCTION

The Iberian lynx *Felis pardina* (Temminck), considered for some time as a subspecies of the European lynx *Felis lynx* (Corbet, 1978), is now recognized as a separate species (Werdelin, 1981; Honacki *et al.*, 1982). It is the most endangered carnivore in Europe (Mallinson, 1978) and probably one of the most threatened in the world. It is placed in Annex II (for species deserving

complete protection) of the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention), and is considered as endangered in the IUCN Red List (IUCN, 1986) and the Spanish Red Data Book (ICONA, 1986). Recently (October 1989) it has been moved from Appendix II of CITES to Appendix I (Jackson, 1990); thus international trade remains forbidden.

Its range has markedly decreased in the last century (Graells, 1897; Cabrera, 1914; Valverde, 1963), and it now appears to be restricted to small areas in the centre and southwest of the Iberian Peninsula (Delibes, 1979). Well-known since former times through literature on hunting and popular books (Chapman & Buck, 1910), the population of Doñana National Park has received the greatest amount of protection and study (Valverde, 1957; Delibes, 1980; Aldama, 1986; Beltrán, 1988).

Many casual accounts and circumstantial evidence strongly suggest that lynx numbers have decreased in recent years in the Doñana area (e.g. Rau *et al.*, 1985). A detailed knowledge of both the exact status and distribution, and the factors which govern them, is necessary to halt this trend towards extinction.

The objectives of the present study are: (1) to map lynx presence in the study area; (2) to determine relative abundance of lynx in each of the areas occupied and to estimate the size of the population; (3) to relate distribution and abundance to different environmental variables; (4) to discuss the main risks for the survival of this lynx population; and (5) to propose measures to prevent its extinction.

STUDY AREA

We selected an area of approximately 2750 km² in SW Spain, which included Doñana National Park and its peripheral buffer zone (773 km²) and their surroundings. The study area was bordered on the south and west by the Atlantic Ocean, to the east by the Guadalquivir River, and to the north by the alluvial plain of the River Tinto and the intensively cultivated high ground of the Aljarafe (Anon., 1989) (Figs 1 and 2).

The study area has been often described since Valverde (1958). It is a generally flat region, with some undulations in the north. The eastern third is marsh or marisma, clayey flats formed from fluvial deposits which are flooded in winter (apart from drained, cultivated polder areas); in the remaining areas sandy soils of aeolian deposits of marine origin dominate. Traditionally the area has been sparsely populated, being used for hunting and extensive agriculture, with centres of population placed in the northern third. However, in recent years irrigated agriculture and coastal tourism

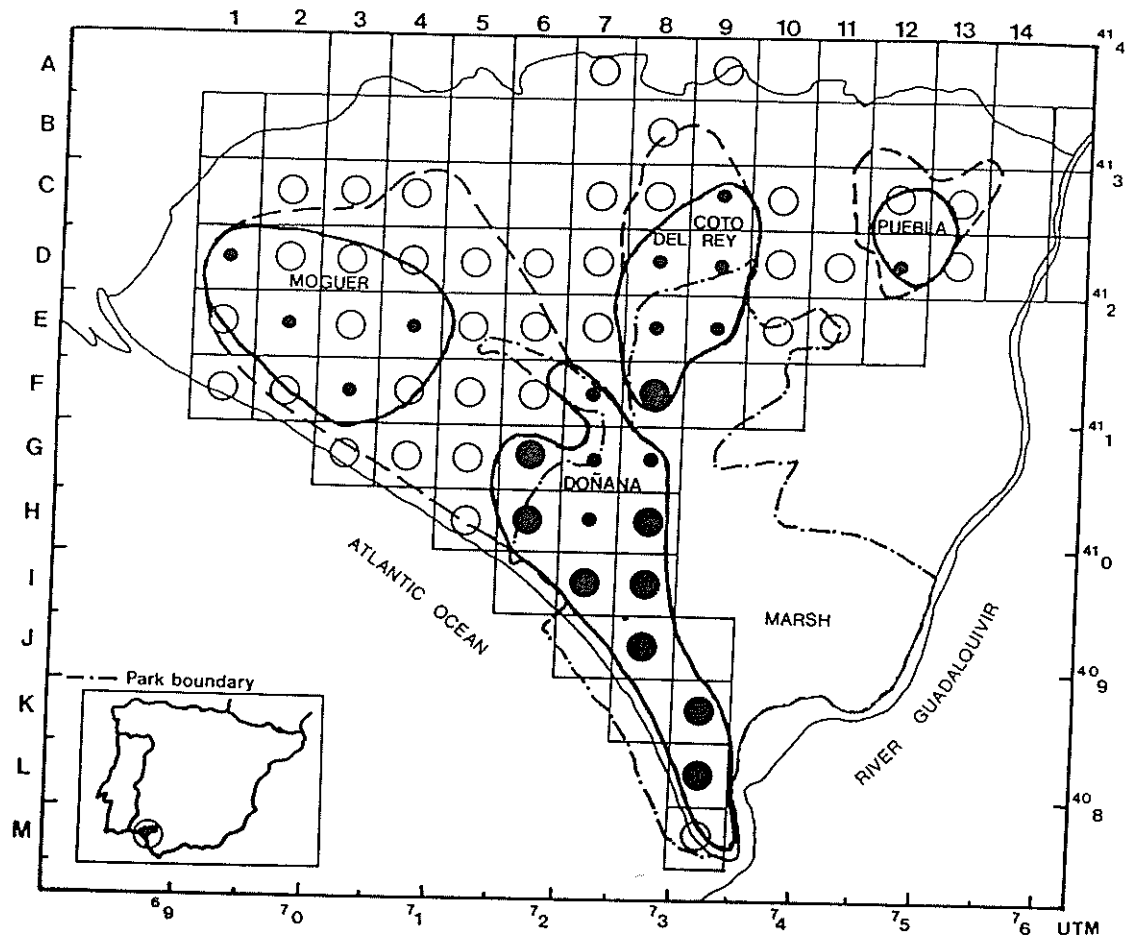


Fig. 1. General sketch of the study area. Squares are 5×5 km. ● (Lynx high abundance and breeding) and ○ (lynx low abundance and improbable habitual breeding) represent positive presence samplings; ○, negative samplings—the remaining squares were assumed to be negative; —, nuclei (see text for details); ----, potential area for stable breeding populations.

have been developed to a large degree, with a considerable increase in human population and per capita income. The climate is subhumid Mediterranean, with rainy, mild winters and hot, dry summers.

Seven main vegetation units can be distinguished (Fig. 2)

- (1) cultivated land (43% of the surface area), exploited for crops not requiring irrigation (mainly olive trees *Olea europaea*, and vines *Vitis vinifera*) and irrigated crops (mainly strawberries and fruit trees);
- (2) pine plantations (16% of the area) of *Pinus pinea*, exploited for wood and edible pine seeds;
- (3) *Eucalyptus* sp. plantations (15% of the area) exploited for wood;
- (4) matorral or Mediterranean scrub (3% of the area), with dense plant cover and isolated cork oaks, although largely devoid of trees; species such as *Halimium* sp., *Rosmarinus* sp., *Erica* sp. and *Calluna vulgaris* dominate;

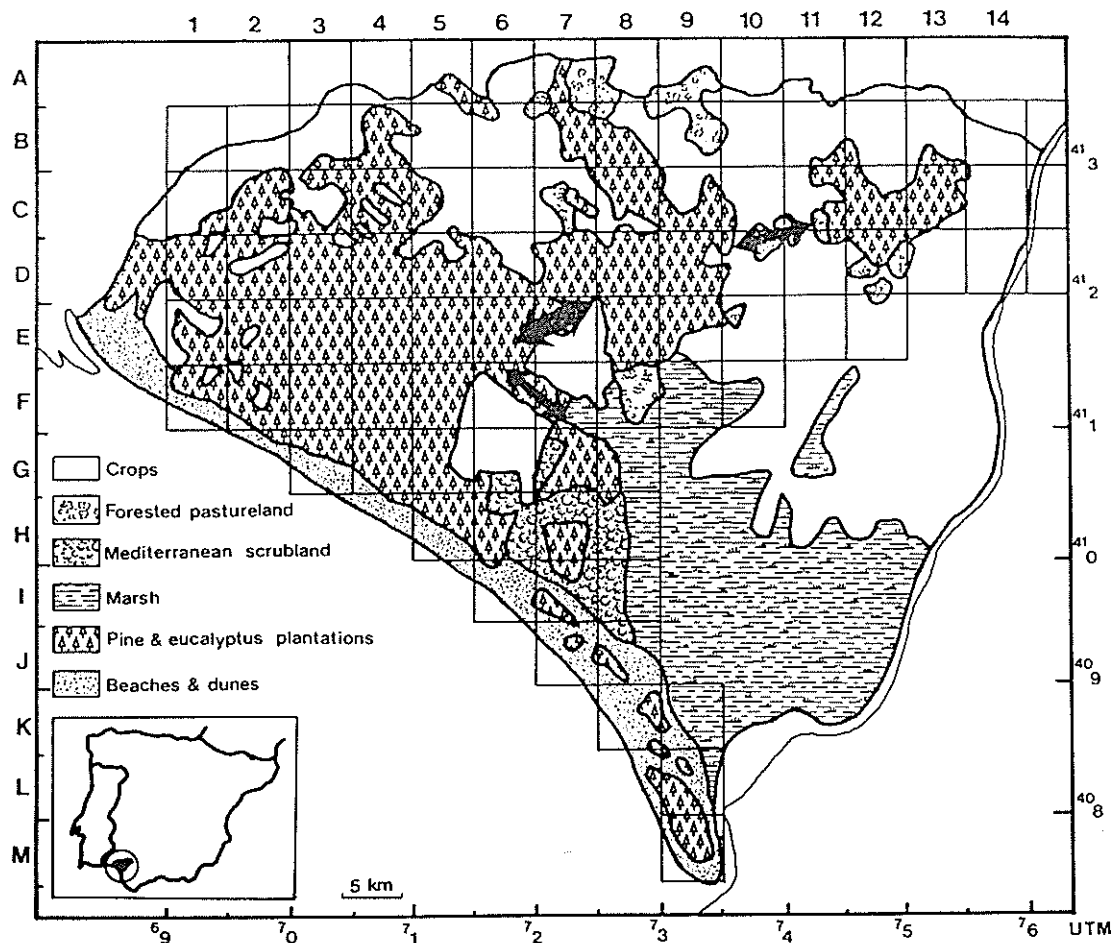


Fig. 2. Vegetation units and sketch plan for lynx management and conservation in the Doñana area. Management should mostly concern the pine and *Eucalyptus* plantations in order to reach the potential reproductive area (see Fig. 1). Arrows indicate the places where contact between subpopulations and nuclei are recommended.

- (5) dehesa or forested pastureland (3% of the area), with scattered *Quercus suber* and variable amounts of understorey cover in between;
- (6) marisma (15% of the area), described above;
- (7) beaches and dunes (5% of the area), a coastal area composed of bare sand dunes and dune hollows with pine trees.

METHODS

Fieldwork, undertaken between December 1986 and March 1987, consisted of a search for signs of lynx presence, in particular, tracks and droppings. In moist sand, after rain, tracks are easily recorded and recognized, while lynx behaviour in depositing faeces at the crossroads of trails and paths (Robinson & Delibes, 1988) facilitates this type of search, which would otherwise not have been feasible. The use of droppings (Mason &

Macdonald, 1986) and tracks (Van Dyke *et al.*, 1986; Thompson *et al.*, 1989) to establish the presence and occasionally to estimate the density of carnivores is well known.

For sampling, the study area was divided into 120 squares (5×5 km) (Fig. 1). *A priori*, 60 of these were considered unsuitable for lynx, being entirely cultivated or marisma, which are not used by the species (personal observation). In each of the remaining squares, the area or areas most suitable for lynx were selected subjectively. Between 1.5 and 6 man/hours (mean 2.25; $n = 73$) were spent in searching for lynx signs. On a few squares, two different samplings were made.

All 60 squares were searched for at least 90 min, the total number of signs discovered being counted (a single pile of scats or a continuous set of tracks being considered as only one sign). After 90 min, searching was discontinued once a sign had been found. The results were considered negative if no signs were found after searching for six man/hours. For all positive squares, an index of the relative abundance of signs was obtained by dividing the number of signs found by the time in hours devoted to searching.

By means of intensive radiotracking since 1983 (J. F. Beltrán and J. J. Aldama, pers. comm.; personal observation), the number of lynx in two squares of the study area (H8 and I8) was known fairly accurately. We also knew of other squares where lynx had been permanently present and/or where breeding had been usual in the last five years. The lowest index of sign abundance in all these squares was 1.8. We used this value to distinguish between squares with low lynx density (< 1.8) and squares with high density (> 1.8).

Absolute numbers of lynx were estimated in two ways. A first very simple approximation consisted of ascribing one individual to each low-density square and four individuals to each high-density square, as these figures approach average numbers known in squares where radiotracking is carried out (zero individuals were ascribed to squares where searches were negative, even when before or after the fieldwork we knew of the occasional presence of lynx there). The second approximation assumed a direct relationship between the index of sign abundance and lynx numbers. In the squares H8 and I8, we estimated that there were 1.38 lynx (including adults and independent young, but not cubs still tended by their mother) per sign/hour. We multiplied the indices of sign abundance by this factor in order to obtain figures of actual lynx abundance in each square.

In addition to the number of lynx signs, we recorded the following information in each of the 73 samplings

- (1) type of vegetation, distinguishing between woodland, scrub, matorral, and other, and for each of these noting the constituent

- species and ground cover (estimated by sight) under four categories: absent, scarce, intermediate and dense;
- (2) presence and abundance of rabbits, estimated by sight from the number of sightings and signs (scrapes, pellets and burrows) under four categories: absent, scarce, intermediate and dense.

To relate the presence and abundance of lynx signs with habitat characteristics we used the *G* test of statistical independence (Sokal & Rohlf, 1979).

RESULTS AND DISCUSSION

Distribution and abundance

Lynx presence was detected in 23 of the 120 squares, representing 19% (approximately 522 km²) of the study area and 39% of the potential area (that is, the 60 squares searched for signs). Within the National Park, 83% of squares searched were positive and outside it only 19%.

The method used provides a snapshot of lynx presence at the moment when the sampling was undertaken. For other dates, some positive squares would probably have been negative and vice versa. It could also be that in some instances there was insufficient search effort. However, the first lynx sign was found within the first 0.5 hour/person on 44% of positive squares and within the first 1.5 hour/person on 90%, suggesting that sampling effort was adequate.

Only 31% of the positive squares have a high density of lynx (more than 1.8 signs/hour search effort). In the remaining 69%, the lynx population must mainly have consisted of wandering individuals, although isolated instances of breeding have been known.

Depending on the approximation used (see Methods), we estimate the number of lynx in the study area as 40 (assuming the relative abundance of signs proportional to the number of individuals) or 50 (assuming each square of low density carries one individual and each square of high density carries four). According to estimates of population structure derived from the radio tracking studies cited, these figures could correspond to between 10 and 15 breeding females.

The distribution of lynx was uneven, with positive squares clumping in nuclei or patches relatively isolated from one another. One nucleus in the northwest (Moguer), a small one in the east (Puebla), and a large central nucleus were distinguished (Fig. 1), the last being divided by an area of open marisma and a large cultivated area. As none of the 25 individuals radiotracked in the southern part have ever been found in the northern

TABLE 1
Positive Squares and Absolute Number of Lynx Signs in Each Nucleus

	<i>Positive squares</i>	<i>Lynx signs</i>	<i>Estimated numbers^a</i>	<i>Estimated density (ind/100 km²)^b</i>
South subpopulation				
Moguer	4	5	3	3
Doñana	12	66	34	11.3
Total	(16)	(71)	(37)	(9.2)
North subpopulation				
Coto del Rey	6	19	7	4.6
Puebla	1	3	1	4
Total	(7)	(22)	(8)	(4.5)
Total study area	23	93	45	7.8

^a Numbers are averaged from both methods (see text).

^b Density has been calculated not only for suitable habitat but also for all the surface area of positive squares.

section (J. F. Beltrán and J. J. Aldama, pers. comm.; personal observations) they were treated as separate nuclei (Doñana and Coto del Rey).

In practice, communication between the Moguer and Doñana lynx is known (J. F. Beltrán, pers. comm.) and the small size of the Puebla nucleus (only one individual estimated, Table 1) suggests that it is composed of wandering animals, rather than breeding, from the Coto del Rey nucleus. Thus we can distinguish two subpopulations, a southern (Doñana and Moguer), that would include 80% of all individuals, and a northern (Coto del Rey and Puebla) accounting for 20% (Table 1).

Between 76% and 80% of the total number of lynx are found in the National Park, another 10% in the adjacent area, the remainder being some distance from it. Within the Park, between 30% and 50% of the lynx occupy the maquis-marisma ecotone, locally called La Vera.

The fragmentation of the Doñana lynx population is a serious threat to its survival (Diamond, 1984), even more so if the small size of this population (and especially its subpopulations) is taken into account. From a genetic point of view, the fragmentation makes this population of Iberian lynxes theoretically non-viable (Soulé, 1980; Shaffer & Samson, 1985). Moreover, the Doñana lynxes at present suffer heavy mortality by illegal trapping and shooting, and as road casualties, especially at the limits of their range (J. J. Aldama, P. Ferreras and J. F. Beltrán, pers. comm.). This prevents contact between the nuclei and increases the rate of extinction.

TABLE 2
Per Cent of Positive Samplings in Relation to Environmental Factors

<i>Environmental factors</i>	<i>Absent</i>	<i>Scarce</i>	<i>Intermediate</i>	<i>Dense</i>
Woodland	71.4	41.7	28.6	26.3
Shrubs	25.0	4.8	66.7	50.0
Maquis	0.0	13.6	44.7	55.6
Humid habitats ^a	18.8	—	—	64.0
Rabbits	0.0	9.1	25.0	58.8

For each row 73 samplings were taken into account, 25 being positive and 48 negative.

^a Only two categories (present-absent) were considered.

Relationship with environmental factors

The presence of lynx is positively correlated with the cover of matorral ($p < 0.01$) and with the abundance of rabbits ($p < 0.005$), but is negatively correlated with *Eucalyptus*/pine woodland ($p < 0.025$) (Table 2).

This avoidance is probably closely related to woodland management practices outside the National Park, as understorey shrubs and bushes are periodically cleared, making permanent settlement and breeding of lynx very difficult. Further, rabbits are scarce in plantations, especially in *Eucalyptus* forests (Soriguer & Rogers, 1980).

The probability of finding lynx signs was found to be higher in squares within Doñana National Park ($p < 0.005$), where vegetation is quite stable and lynx mortality is seldom increased through direct human action. Signs were also found with higher probability in areas of higher edaphic moisture ($p < 0.005$; Table 2), and where rabbits are known to be more abundant in all seasons (R. Villafuerte, pers. comm.).

The type of vegetation and abundance of rabbits in several squares (B8, C8, E5, E6, E10, F1 and F2) would potentially allow the presence of lynx, yet sampling proved negative. High human disturbance was found in these squares, mostly associated with hunting.

Conclusions and conservation proposal

The extinction of mammals in similar circumstances to those of the lynx in Doñana has previously been reported (Diamond, 1984; Seidensticker, 1987). The introduction of measures to conserve this lynx population is both necessary and urgent. Measures should aim at conservation of usable habitat and opportunities for genetic interchange with individuals of other

populations (Soulé, 1980; Diamond, 1984). The survival requirements for lynx are the protection of areas of matorral with high cover, medium or high rabbit density and low negative human impact. Conservation and management objectives should be

- (1) to improve the habitat, especially in plantations of *Eucalyptus* and pine trees, favouring matorral scrub for lynx and pasture for rabbits. This would help to extend the present breeding range (Fig. 2);
- (2) to facilitate the interchange of individuals between subpopulations, through the creation of corridors of optimal habitat across the squares F7, F6, E6, E7, D7 and D10, C11 and D11 (Fig. 2);
- (3) to increase research, mainly about dispersion and causes and rates of mortality, and to continue with the animal monitoring.

These objectives must be supported by strict enforcement of existing administrative and legal protection measures. With this action, a demographically viable population (Shaffer & Samson, 1985, for grizzly bear *Ursus arctos*) might be achieved.

A fourth and more ambitious objective would be to link the Doñana lynx population with the nearest neighbouring populations in the Iberian Peninsula by the creation of protected corridors of vegetation so as to allow natural interchange, or through genetic enrichment by means of artificial interchange between populations (Soulé, 1980).

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