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Current range and status of the Iberian lynx *Felis pardina* Temminck, 1824 in Spain

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The current distribution of the Iberian lynx *Felis pardina* is outlined and its population size in Spain estimated at about 95% of its world range. There are 48 separate breeding areas, generally small in size. In addition, 32 non-breeding areas have been located, and 50 areas where lynx presence is uncertain, some associated with, and others separated from, breeding areas. A major part of the range supports low lynx densities. Range fragmentation is the most noteworthy feature of the distribution pattern, although dispersal might link some adjacent nuclei. Nine genetically isolated populations are recognized, although probably only two, accounting for about 70% of the total population, are viable in the short term. The Spanish population size is estimated at about 1100 individuals, with fewer than 350 reproductive females. The risks arising from this situation are analysed and conservation policies proposed.

INTRODUCTION

The pardel or Iberian lynx *Felis pardina*, Temminck 1824 has been considered by several authorities as a subspecies of the Eurasian lynx, *Felis lynx* L. (Ellerman & Morrison-Scott, 1951; Corbet, 1978; Corbet & Hill, 1986). However, coexistence of both forms without hybridization has been proved from the Pleistocene to recent times (Kurtén, 1968; van den Brink, 1970, 1971). In addition, studies of the skull morphology and dentition reveal that the Iberian lynx is the oldest recent lynx species, phylogenetically more separated from *F. lynx* than this species is from *F. canadensis* and *F. rufus* (Werdelin, 1981). The specific status of *Felis pardina* has lately been upheld, including a review of Carnivora systematics (Wozencraft, 1989, supported by Honacki *et al.*, 1982; Werdelin, 1990).

The Iberian lynx has been recognized as the most threatened European carnivore (Mallinson, 1978). It is included in Appendix II of the Bern Convention on the Conservation of European Wildlife and Habitats, and recently has been moved from Appendix II to Appendix I of CITES (Jackson, 1990). In the same way, it is catalogued as 'Endangered' in the IUCN Red List of Threatened Animals (IUCN, 1988) and the Spanish Red Data Book (ICONA, 1986). However, no updated field survey exists on its status and distribution. Iberian lynx distribution maps have been based on compilations of unsystematic reports (see Valverde, 1963, Garzón, 1978, and Delibes, 1979, for Spain, and Palma, 1980, for Portugal). All identified a few isolated populations in the southwestern mountains, and sometimes also some scattered localities in the north and east of the Iberian pensinsula. Nevertheless, remarkable differences occur in the maps and population estimates.

The aims of this paper are to describe precisely the current distribution and numbers of the Iberian lynx, and to discuss the conservation risks arising from the pattern of distribution and population size.

METHOD

Between November 1987 and May 1988 4000 questionnaires requesting information on the presence of lynx were sent to rangers, game boards, taxidermists, and naturalists' associations in potentially favourable areas for the lynx (i.e. the southern two-thirds of peninsular Spain). Thirty-five per cent of the enquiries were answered. Of these, 24·5% (255) contained some positive information. Simultaneously, advertisements were inserted in hunting and nature journals requesting reports, and the scattered published and unpublished data on lynx distribution collected.

From November 1987 to October 1988 field work was focused on: (1) checking reports from the postal enquiries by interviewing lynx observers or hunters; (2) obtaining new reports from those who could not be reached by post, such as private gamekeepers, shepherds and trappers, and (3) making a rough evaluation of habitat features, such as vegetation cover, prey abundance and human activity (land use) that have previously been related to lynx presence (Delibes, 1979; Palomares *et al.*, 1991).

The field study area covered 74 000 km^2 and about 2500 people were contacted (average 3·4 interviews/100 km^2). On a large scale, sampling intensity was similar over the whole of the study area.

Reports were carefully reviewed, only being accepted as positive (1) if they were supported by evidence such as fur, skeletal remains, tracks, faeces, and/or photographs, verified by ourselves; or (2) in the absence of definite proof, when several accurate lynx descriptions from several experienced observers were in agreement, locating the species in the same area and at the same time.

Combining both methods—mail data and field checks—reduces the disadvantages of using each alone (Filion, 1980), and provides a high efficiency/effort ratio.

A total of 1583 positive reports for the period 1978–1988 were accepted (a similar number were rejected). A current distribution map was prepared from these reports, assuming no significant changes in range boundaries during the present decade. (This may be an unrealistic assumption so that our results may be over-optimistic.)

In this map we were able to delimit two types of areas:

(1) breeding areas, where there was a continuous spatio-temporal pattern in the distribution of reports, and data on breeding occurred (records of kittens or pregnant females).
(2) areas of occasional lynx presence, where there were few reports, separated in time (>5 years) and/or through space (>10 km between contiguous locations), and there were no records of breeding.

Furthermore, we regarded as areas of uncertain presence those where reports (usually <10) tended to aggregate within a few square kilometres. Because all of these isolated records were located far from those where lynx presence was confirmed and no consistent evidence was found, we cannot either confirm or reject lynx presence there.

Assuming some direct relationship between lynx density and frequency of reports, the proportion of breeding data and habitat quality (according to the standard lynx habitat previously described; Delibes, 1979; Palomares *et al.*, 1991), we distinguished subjectively three classes of breeding areas: (1) high-density (many records, more than 10% related to breeding, with good-quality habitat); (2) intermediate (breeding data accounting for less than 10%); (3) low density (breeding rarely recorded).

To estimate numbers we used as a reference the number of lynx living in 50 km^2 of the Doñana region. Here lynx density was estimated both from sign counts (Rau *et al.*, 1985) and radio-tracking surveys (Beltrán, 1988; unpublished data), as 16 individuals/100 km^2, excluding kittens (Palomares *et al.*, 1991). In the light of our experience in the Doñana area, where the relationship between lynx reports and lynx abundance is known, we were able to assign discrete values of relative density to each of the remaining areas, taking into account the quantity and quality of the reports on lynx presence obtained there. As a rule, breeding areas with high lynx density were estimated to support between 13 and 21 individuals/100 km^2, intermediate areas between 8 and 12, and those of low density between 4 and 7. We assigned to the areas of occasional presence densities between 2 and 3 individuals/100 km^2.

RESULTS

Figure 1 shows the current breeding range of the Iberian lynx. Although not an objective of our field study, data from Portugal (Palma, 1980) were included to represent the entire probable world breeding area for *F. pardina*.

The pardel lynx occurs on all the four southern mountain chains of Iberia, and also in a flat area at sea level, near the mouth of the Guadalquivir. A simple analysis shows that the lynx inhabits relatively undisturbed Mediterranean habitats far from the main human settlements. Except in Doñana (at sea level), it occupies areas between 400 and 1300 m altitude, where there is Mediter-

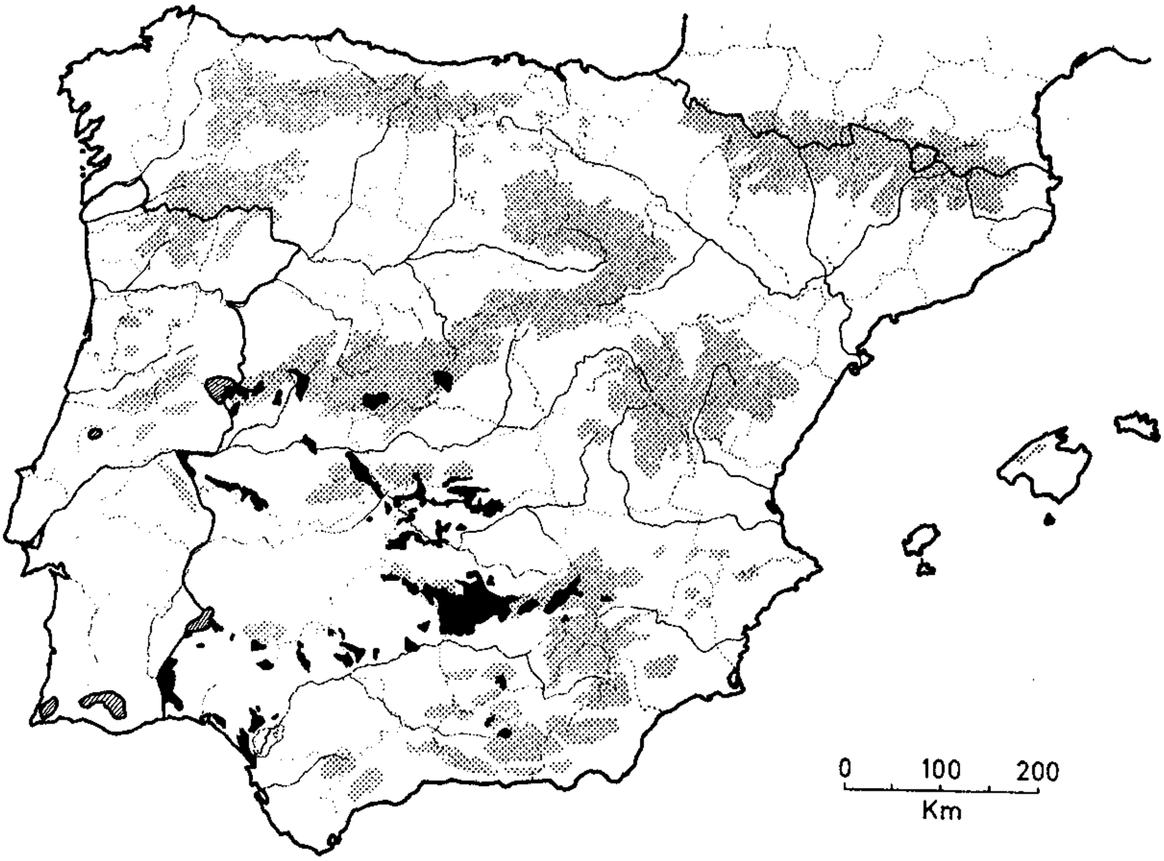

Fig. 1. Current breeding range (■) of the Iberian lynx. ▨, Portuguese data from Palma (1980) and others unpublished. ▩, mountains >1000 m. Principal Iberian rivers are also shown.

ranean forest or shrubland. High vegetation cover, an abundance of rabbits (which prefer a mixture of cover and open grassland) and low human influence seem to be important features of the lynx habitat. In mountains, rocky places are usually selected for breeding, usually coinciding with hunting reserves and natural parks.

The lynx breeding range occupies about 11 000 km^2, containing over 48 breeding areas of greatly varying size. Around the breeding areas, 32 areas of occasional presence have been established (Fig. 2), whose total extent is estimated to be about 3900 km^2, although the limits are difficult to draw. Since the three isolated lynx nuclei reported in Portugal hardly account for 700 km^2 (Palma, 1980), we estimate that at least 95% of the pardel lynx range occurs in Spain, the area covered by our study.

Taking into account the ability of the species to disperse (studies in Doñana by Beltrán, 1988, and one of the authors, unpublished data, recorded young dispersing more than 30 km), it seems realistic to consider the 48 isolated breeding areas and 32 areas of occasional presence as nine genetically isolated populations, corresponding to the Western Sierra Morena (SMH), Doñana (DOÑ), Central Sierra Morena (SMC), Subbetic Mountains (SUB), Central Spain (CP, including Eastern Sierra Morena, SMO, and Montes de Toledo-Villuercas, MTO-VIL), Sierra de Gata (GAT), Sierra de Gredos (GRE), Alto Alberche (MAD) and Sierra de San Pedro (SSP) (Fig. 2).

In addition, it is possible that lynx occur in 50 areas where their presence is uncertain, scattered mainly over eastern and northeastern regions (Fig. 3).

The extent of the breeding areas, estimates of density, and population size are shown in Table 1. Twelve high-density areas (>13 individuals/100 km^2, mean size 150 km^2; range 25–500 km^2) account for 17% of the total breeding range. The maximum estimated absolute density reaches 21 individuals/100 km^2 in a 500-km^2 zone in area 26.

Nineteen medium-density areas (8–13 individuals/100 km^2, mean size 200 km^2; range 10–840 km^2) account for 36% of the total breeding area. The remaining 47% concerns 31 low-density areas (5–8 individuals/100 km^2), with similar size variation to that of the medium areas, but tending to be smaller ($\bar{x}$ = 161 km^2).

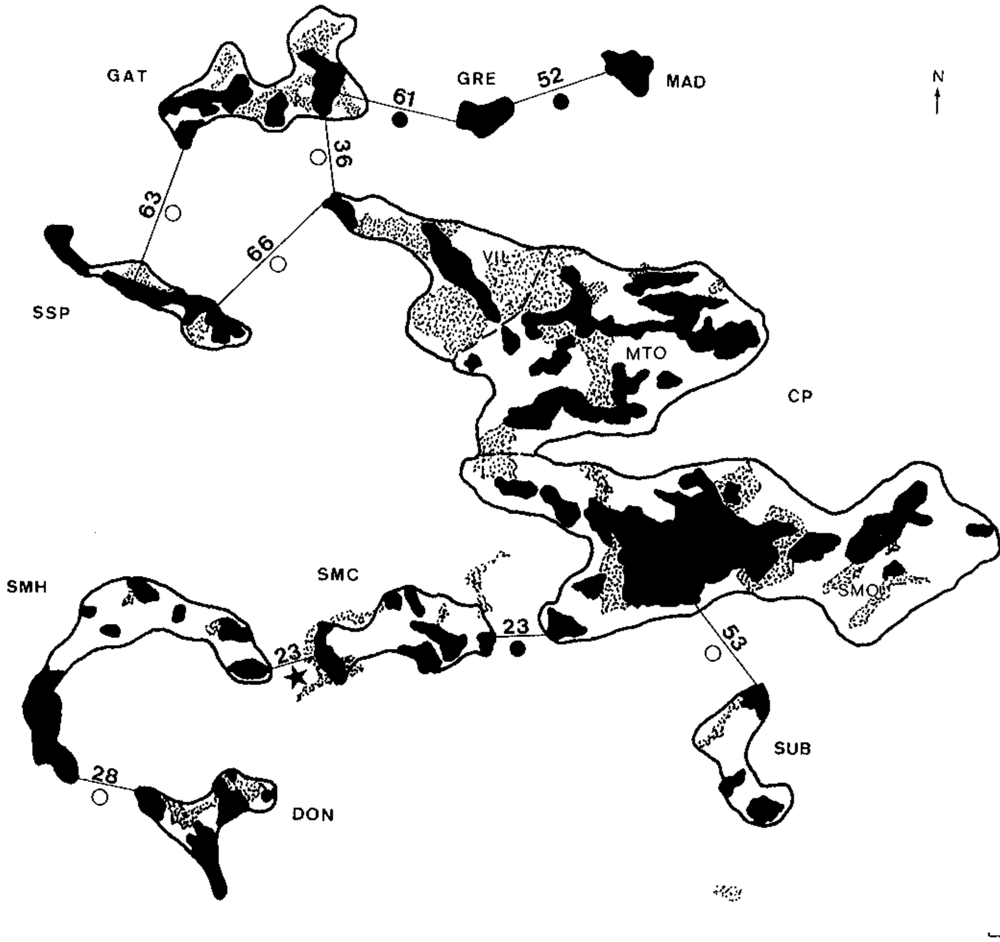

Fig. 2. Lynx distribution in Spain. Continuous lines surround the nine estimated populations, including breeding (■) and occasional presence (▩) areas. Three subpopulations (VIL, MTO, SMO) are also indicated by broken lines. Straight lines represent minimum barrier breadth (km). Symbols indicate the degree of barrier penetrability for lynx: ★, high; ●, low; ○, null. GAT, Sierra de Gata; GRE, Sierra de Gredos; MAD, Alto Alberche; SSP, Sierra de San Pedro; CP, Central population (VIL, Villuercas; MTO, Montes de Toledo; SMO, Eastern Sierra Morena); SMH, Western Sierra Morena; SMC, Central Sierra Morena; DOÑ, Doñana; SUB, Sierras Subbéticas.

As expected, a significantly positive correlation exists between estimated population size and area size (r = 0·985, p < 0·0001), but not between lynx relative density and area size.

A decreasing density is noted from south to north on a peninsular scale, and from east to west within each mountain range. The highest relative densities are found in Doñana, eastern Sierra Morena, and eastern Montes de Toledo.

The estimated total population size is about 1100 individuals, half occurring in the SMO population. In the Doñana area we estimate there to be 49 lynx (Table 1), while Palomares *et al.* (1991) established a population size for the same area of 40–50 individuals. Accepting these limits of variation for all the range, the total Spanish lynx population would comprise 880–1150 individuals.

The age-ratio is not known for any of the Iberian lynx populations. The proportion of young in non-exploited populations of *Felis rufus* amounts to 16 (Lembeck & Gould, 1979) to 55% (Toweill, 1980, in Anderson, 1987). Because a male may mate with several females, productivity is limited by the number of adult females (as in the bobcat, Knick, 1990). Assuming the average proportion of juveniles to be 35% and the sex-ratio close to 1:1, the number of breeding female lynx in Spain probably does not surpass 350 individuals.

DISCUSSION

The current distribution of lynx, as estimated in our study, roughly agrees with maps offered some time ago by other authors (Valverde, 1963; Garzón, 1978; Delibes, 1979), as most of the occupied areas are in the mountains of the southwestern quarter of the Iberian peninsula. However, none of the previous maps attains the accuracy of that presented here, and never before has an estimation

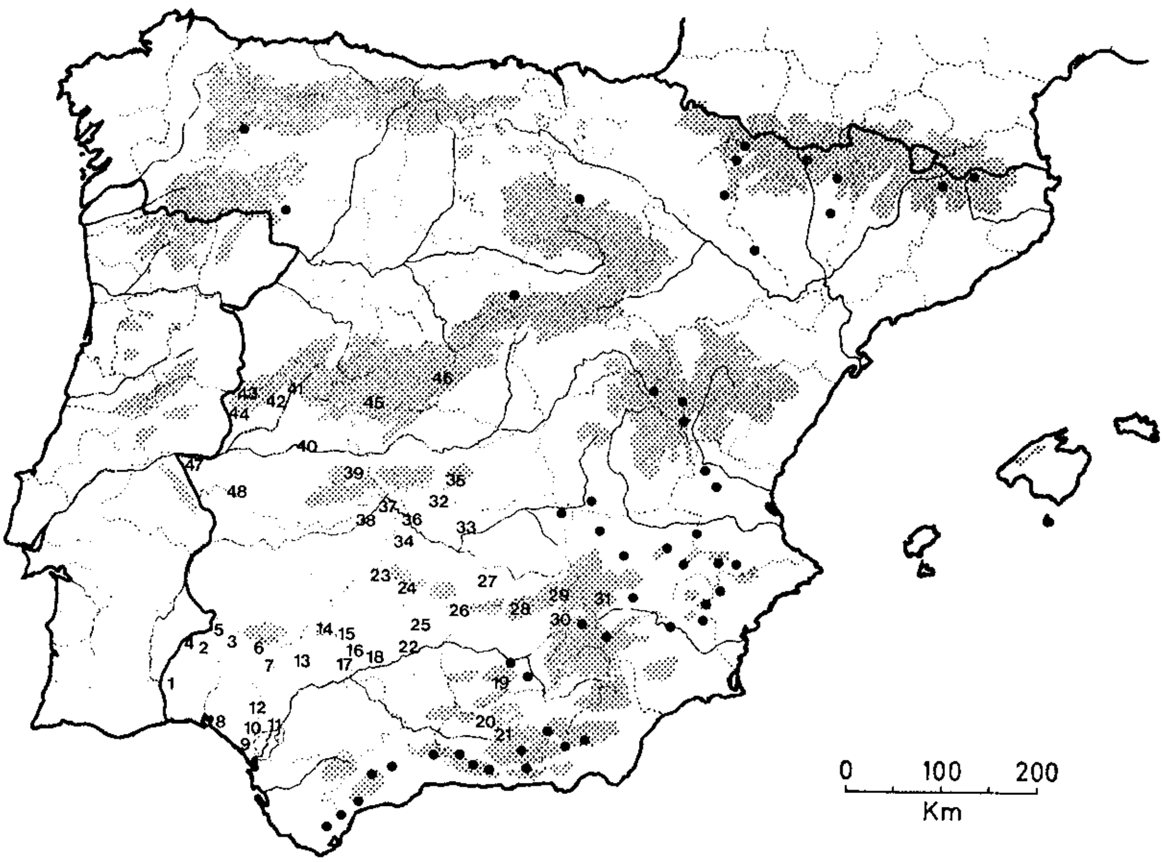

Fig. 3. Areas with uncertain lynx presence (●). Sources for Pyrenees are Jordán *et al.* (1988) and J. Ruiz-Olmo (pers. comm.) and for northwest region, Clevenger (1987) and Grande & Hernando (1982). Numbers correspond to the location of breeding areas (see Table 1).

of differential densities of each lynx area been given.

Because both lynx numbers and range have declined since 1950 (Delibes, 1979; Rodríguez & Delibes, 1990), new localities indicated by our work cannot be attributed to recent recolonization, but to biased or absent information in earlier studies.

Small northern and northeastern populations suggested by Valverde, and then questioned by Garzón and Delibes, remain unconfirmed, despite occasional reports from these regions (Grande, 1978; Grande & Hernando, 1982; Clevenger, 1987; Jordán *et al.*, 1988; J. Ruiz-Olmo, pers. comm.). Our data are insufficient to prove lynx presence in these areas. Possible lynx presence has also recently been reported in the French Pyrenees (Chazel, 1989), although the last clear evidence found there was a skull of *Felis lynx* dating from about 1950 (Beaufort, 1965).

Estimated population sizes published in the 1970s were also based on fragmentary data, but were fairly correct, if slightly optimistic. Thus, Urquijo (1975) and Garzón (1978) calculated 1200–1600 and 1000–1400 adult lynx, respectively. IUCN (1978), supported by Garzón's data, accepted 1000–1500 individuals, including the Portuguese population. On the other hand, the Spanish Red Data Book later reported about 400 lynx (ICONA, 1986).

Although the subject deserves closer study, three phases, characterized by different main causal reasons, can probably be recognized in the history of the declining range of the Iberian lynx. In the first period, from antiquity until the 1950s, hunting was probably the most important cause of lynx disappearance, as happened with *Felis lynx* in Central Europe (Eiberle, 1972). In this phase the lynx disappeared from good potential areas now separated from occupied nuclei by a vast extent of unsuitable habitat. Natural recolonization is thus scarcely possible. In the second period, since the 1960s, habitat destruction and scarcity of rabbits (the main lynx prey; Delibes, 1980) due to myxomatosis were probably the more important reasons for lynx decline (Garzón, 1978; Delibes, 1979). In this phase, coinciding with rapid economic development in Spain, many dams, highways and railways were built, and most Mediterranean

Table 1. Area size (AS), estimated average absolute density (AD), and estimated population size (PS) in the 48 breeding areas and the nine lynx populations in Spain

Breeding area[a]	AS (km²)	AD (individuals/ 100 km²)	PS (no kittens)
1 Andévalo	235	6·4	15
2 Aroche	26	6·4	4
3 Cumbres	27	4·8	4
4 Rosal	17	4·0	1
5 Encinasola	51	9·6	5
6 Aracena	82	6·4	5
7 Zufre	113	6·4	7
Occasional presence	485	2·4	12
SMH population	1036	4·5	53
8 Moguer	131	4·8	6
9 Doñana	168	16·0	27
10 Coto del Rey	52	16·0	8
11 Aznalcázar	38	4·0	1
12 Torrecuadros	15	4·0	1
Occasional presence	135	4·0	6
DOÑ population	539	9·1	49
13 Viar	130	9·3	12
14 Alanís	11	8·0	4
15 Albarrana	9	8·0	4
16 Bembézar	158	8·8	14
17 Retortillo	101	11·2	11
18 Guadiato	79	9·6	8
Occasional presence	270	3·8	10
SMC population	758	7·5	63
19 Mágina	110	4·8	5
20 El Zegrí	66	6·4	4
21 Harana	141	8·0	12
Occasional presence	227	2·6	6
SUB population	544	4·8	27
22 Guadalmellato	121	11·2	14
23 Santa Eufemia	81	12·8	10
24 San Benito	127	7·7	10
25 Arenoso	102	14·4	15
26 Andújar	2914	12·6	372
27 Mudela	43	6·4	4
28 Montizón	219	8·0	17
29 Guadalmena	361	12·8	46
30 Las Villas	30	6·4	4
31 Alcaraz	52	6·4	4
Occasional presence	1244	3·2	40
SMO subpopulation	5294	10·1	536
32 Montes	1239	9·1	112
33 Picón	85	8·0	7
34 Guadiana	582	7·8	46
35 Castañar	159	11·2	18
36 Valdehornos	134	6·4	9
37 Cijara	99	6·4	6
38 Herrera	24	4·8	4
39 Villuercas	437	7·0	31
40 Monfragüe	175	6·4	11
Occasional presence	884	3·2	28
MTO–VIL subpopulation	3818	7·0	272

Table 1—*contd.*

Breeding area[a]	AS (km²)	AD (individuals/ 100 km²)	PS (no kittens)
CP (= SMO + MTO + VIL) populations	9112	8·8	808
41 Granadilla	362	6·1	22
42 Santa Cruz	69	6·4	4
43 Gata	297	6·4	19
44 Cilleros	96	6·4	6
Occasional presence	405	1·6	7
GAT population	1229	5·0	58
45 Candeleda	374	4·8	18
GRE population	374	4·8	18
46 Alto Alberche	268	4·8	13
MAD population	268	4·8	13
47 Cedillo	103	6·4	7
48 San Pedro	423	7·4	31
Occasional presence	250	3·2	8
SSP population	776	5·9	46
Spanish Lynx population	14636	7·7	1135

[a]See Fig. 1.

scrublands were converted to agriculture and plantations of pines and eucalyptus, reducing the lynx range and causing the fragmentation of its populations. At present, lack of prey (in addition to myxomatosis, a new viral disease is destroying wild rabbits in Spain; Villafuerte & Moreno, 1991), humanization of the environment—most lynx die on roads, drowned in irrigation wells and captured in traps for rabbits and foxes (Ferreras *et al.*, 1992, this issue)—and the problems derived from fragmentation of populations seem to be the main threats to lynx survival, since direct hunting has been reduced (Rodríguez & Delibes, 1990).

From the point of view of conservation biology, small size, isolation and dispersion of the occupied areas are the more noticeable features of current lynx distribution. This permits us to address the problem as a typical island biogeographic model, in which island (fragment) sizes, estimated density and distance between islands are known, but the possibility of lynx crossing the different inter-island barriers is at present difficult to assess.

Considering only the barriers between the nine isolated populations of Fig. 2, it appears that intensive agriculture in the Tajo and Guadalquivir valleys separates the three northern (GAT, GRE, and MAD) and one southern (SUB) populations, respectively, from a central population (CP). Altered, man-made landscape isolates DOÑ from SMH, and the same factor, along with distance, isolates SSP from CP. Suboptimal habitats may explain the separation between SMC and CP, whereas this and low lynx density in the breeding areas isolate the SMC and SMH populations. Distance and low density seem to be the main causes of the GAT–GRE–MAD barriers. Furthermore, as mentioned above, low lynx density, probably related to scarcity of prey, tends to divide the central population into three subpopulations: VIL, MTO and SMO. In the near future, several new obstacles, including highways, large dams, and fenced-off high-speed railways, might restrict lynx movement and contribute to the process of fragmentation.

Only two subpopulations of CP (SMO and MTO, Fig. 2) are found in areas of more than 2000 km^2, and only these two have 200 or more individuals. The remaining populations never reach 100 individuals, living in areas of less than 1000 km^2. Because of their small size, all populations except perhaps CP are probably not viable in the long term, due to increased vulnerability to stochastic events (Shaffer, 1981). If isolation really occurs between all 48 breeding nuclei, 96% could not reach an effective population size (N_e) of 50, the theoretical threshold below which loss of genetic variability rapidly increases (Franklin, 1980).

Habitat destruction is often responsible for most recent 'normal' extinctions (Wilcox & Murphy, 1985; Diamond, 1989) and this seems to be the main cause of the decline of the lynx population. Our results confirm the endangered status of this rare carnivore, suggesting that fragmentation and human disturbance are the main threats that could lead to the extinction of the remaining populations. In fact, several reduced lynx populations have become extinct in the 20th century, as a result of fragmentation by rural development (see also Ferreras *et al.*, 1992, this issue).

Because of the practical problems of establishing reserves large enough to guarantee the survival of the increasing number of species that become threatened, a change from a species approach to an ecosystem/land-use approach is suggested for conservation strategies (e.g. Grumbine, 1990). A conservation plan for the lynx must be included in a broad Mediterranean ecosystem conservation programme which harmonizes the development of rural areas with the maintenance of habitats and traditional land uses.

In addition, short-term actions, in our opinion, should be focused on three goals:

(1) prevent new marginal habitat losses or fragmentation by setting up protected areas;
(2) guarantee survival of the viable populations, specifically the CP population, which includes about 70% of the total lynx numbers;
(3) manage populations, by increasing numbers in low-density areas, linking adjacent nuclei by natural (corridors) or artificial contact (lynx release, insemination), and through reintroduction (southern Spain) and captive breeding.

More research into the factors that generate barriers and the associated lynx response is needed to understand the fragmentation process and to predict long-term population trends.

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