

Rates and causes of mortality in a fragmented population of Iberian lynx *Felis pardina* Temminck, 1824

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Data are presented on mortality rates of the Iberian lynx *Felis pardina* in Doñana National Park and the surrounding area in southwestern Spain, collected from 1983 to 1989. Data from radio-tagged lynxes and records of lynx mortality were used to assess causes of death. Annual mortality rate, estimated by using the Heisey and Fuller methodology, was 0.37. Human activities were the main cause of lynx mortality in this mainly fully protected area, either directly (illegal trapping: 41.7%; road traffic: 16.7%; hunting with dogs: 8.3%) or indirectly (artesian wells: 8.3%). Only 83% of the annual mortality can be related unequivocally to natural causes. Sex, age, social status, year, and home range situation influenced mortality rates. The trend of this lynx population during the seven years of study revealed serious threats to its survival. This case study exemplified how a small population can approach extinction because of increased mortality due to habitat fragmentation, despite full protection of the main portion of its range.

INTRODUCTION

Many authors have referred to the extinction of species caused by habitat fragmentation (Lovejoy *et al.*, 1984; Diamond 1989). However, there are few descriptions of the extinction process of these fragmented populations. In this paper we analyse the mortality of an isolated and fragmented population of Iberian lynx *Felis pardina* in risk of extinction (Palomares *et al.*, 1991).

The Iberian lynx is considered the most endangered carnivore in Europe (Mallinson, 1978). The total population has been estimated to be about 1000 individuals, distributed in many small and isolated populations in the southwestern Iberian Peninsula (Rodriguez & Delibes, 1992). The Doflana lynx population was estimated at 40–50 individuals in 1987 (Palomares *et al.*, 1991), its range including the protected Doflana National Park (550 km²) and the recently created Doflana Environment Natural Park (540 km²).

Nevertheless, this lynx population has recently

decreased in numbers (Rau *et al.*, 1985; Palomares *et al.*, 1991). Hence, it is important to know the rates and causes of mortality, in order to attempt to reduce them.

The objectives of this study were fourfold:

- (1) to estimate annual mortality rate of the Doflana lynx population from 1983 to 1989;
- (2) to estimate differential mortality rates by sex, age, social status, year and home range situation;
- (3) to determine causes of mortality; and
- (4) to discuss the ability of the current Doflana protected area to enhance lynx survival.

Estimation of mortality rate and anecdotal information on birth rates can allow us to speculate about the annual balance and trends of the Doflana lynx population, and assess management plans for the conservation of the Iberian lynx.

STUDY AREA

Located in southwestern Spain, the study area covers approximately 2750 km², including Doflana

Fig. 1. Sketch of the study area. Road C-445 is marked with an asterisk and the tourist urbanization with a double circle.

National Park (550 km²) and the recently created (1989) Natural Park of the Dofiana Environment (540 km²) (see Palomares *et al.* 1991). There are many detailed descriptions of this zone (Amat *et al.* 1979; Rogers & Myers, 1980). The Doflana area, flat and low, is on the western bank of the Guadalquivir river (Fig. 1). The area is also bordered on the south and west by the Atlantic Ocean, on the north by the alluvial plain of the Tinto river and the intensively cultivated high ground of the Aljarafe, and on the east by the Marismas of the Guadalquivir river.

The land bordering the protected area is under considerable human exploitation. A large development of coastal tourism (in the Matalascaflas urbanization), intensively cultivated (olive trees, vines) and irrigated (fruit trees and strawberries) lands, pine *Pinus pinea* plantations exploited for wood and edible pine seeds in the west and eucalyptus plantations in the north, have increased human pressure in the area in the last 25 years. Several roads connecting villages, especially the

C-445 from El Rocio to Matalascaflas, cross habitats normally occupied by lynxes.

Three lynx nuclei are distinguished by Palomares *et al.* (1991) in the population under study: a large central one occurring mainly in the National Park, but effectively divided into two subnuclei by areas of open marsh and cultivation; a second in the northwest (Moguer), and the smallest one in the east (Puebla). The last two subpopulations are mainly in the unprotected area.

METHODS

Between 1983 and 1989 we radio-tagged 30 lynxes, representing 9523 transmitter-days (Delibes & Beltrán, 1986). Animals were captured with trunk-traps, box-traps and victor No. 2 coil-spring traps (Woodstream Co., USA) with cushioned jaws to avoid injuries. They were immobilized with a mixture of Ketamine and Xylazine, weighed, measured, equipped with radios, and samples of blood

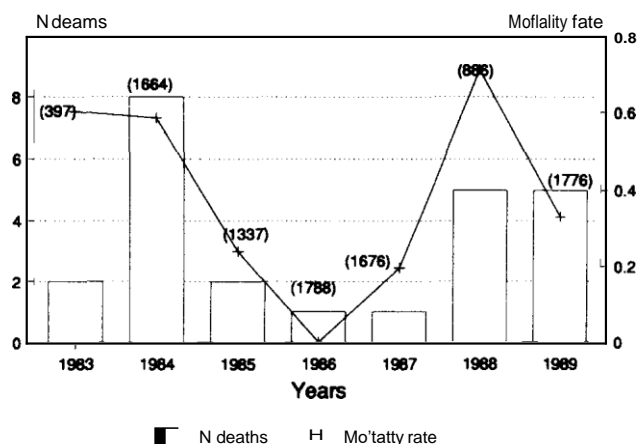


Fig. 2. Variation of the Annual Mortality Rate throughout the study period and number of total dead lynx (with and without transmitter) found each year. The number of radio-tracking days are given in parentheses.

and exoparasites taken. Mortality rates were estimated using the MICROMORT program (Heisey & Fuller, 1985), based on calculating daily mortality rates, according to the total number of radio-transmitter days and deaths of radio-tracked animals occurring in the interval covered (Trent & Rongstad, 1974). The different rates were compared at the $p < 0.01$ level with the test proposed by these authors in the program manual. This employs a statistic based on the corresponding rate estimates, their variances and the covariance (all calculated by the program), and fits into a Z-normal distribution.

All records of dead lynxes in the Dofiana area in the period 1983–89 were used to estimate mortality causes and their relative importance.

Individual lynxes were separated into three age classes: juvenile (under one year old), subadult (1–2 years old), and adult (over two years old), according to dentition, weight and other physical

measurements (Beltrán, 1988). By using radio-tracking data on the lynx space-use patterns, we have distinguished three social classes in the Dofiana lynx population: residents (individuals holding a permanent home range); dispersers (individuals with no established home range, frequently juveniles and subadults dispersing from their natal ranges, but also some adults ejected from their home ranges by competitors); and pre-dispersant young (kittens and juveniles that live in their natal range) (Griffith & Fendley, 1986; Delibes, 1989). Mortality rates were estimated for each class of age, sex and social status.

RESULTS

Annual mortality rate

Average annual mortality rate (AMR) from radio-tracking data was 0.37 ± 0.025 (mean \pm standard error) with high variability during the study period (SD = 0.26; Fig. 2), and significant differences between 1984 and 1986 ($Z = 3.20$, $p = 0.001$) and 1986 and 1989 ($Z = 2.39$, $p = 0.008$). Mortality seemed to be cyclical, with peaks in 1984 and 1988 and a minimum in 1986. Social status appeared to have the strongest effect on mortality rate (Table 1), dispersers having the highest mortality (male AMR = 0.86, female AMR = 0.70). As stated, dispersers included adults expelled from their territory (two cases, found dead in 1984 and 1987). Pre-disperser individuals had the lowest mortality rate, although in this group only individuals older than five months are included, since animals younger than this age cannot be fitted with a transmitter. None of the seven young male lynxes radio-tracked died in their natal range, before dispers-

Table 1. Annual mortality rates (AMR), 95% confidence intervals (CI), number of radio-tracking days (RD), number of tracked individuals (IND) and number of recorded deaths (DEA) by different categories of sex and social status

Sex and social status	AMR	95% Confidence interval	RD	IND	DEA
Resident male	0.12	0.00–0.32	2791	9	1
Resident female	0.21	0.00–0.43	3110	5	2
Pre-dispersing male	0.00	0.00–0.00	1247	7	0
Pre-dispersing female	0.31	0.00–0.67	974	8	1
Dispersing male	0.86	0.33–0.97	1097	12	6
Dispersing female	0.70	0.00–0.97	301	4	1
Total male	0.43	0.16–0.62	5135	17	7
Total female	0.28	0.01–0.48	4385	13	

The total number of males and females does not coincide with the addition of numbers in each category because some individuals were tracked while belonging to different categories.

Table 2. Causes of mortality: annual mortality rates (AMR) due to each cause, percentage (%) of the total AMR, confidence intervals (CI), number of deaths for the radio-tagged sample (DEAR); total of deaths (DEAT) (tagged and not tagged) and percentage (%) of total deaths due to each cause

	Radiotagged			Total		
	AMR	%	CI 95%	DEAR	DEAT	%
Illegal trapping	015	417	003—028	4	8	333
Road	006	167	000—014	2	5	208
Unknown	006	167	000—014	2	4	167
Wells	003	83	000—009	1	3	125
Natural	003	83	000—009	1	2	83
Dogs	003	83	000—009	1	1	42
Accident					1	42
Total	037		018—051	11	24	

ing, and only one female out of the eight radio-tagged individuals died (Table 1). Mortality rates were greater in males than in females, though not significantly ($Z = 0.91, p = 0.184$).

Causes of death

During the seven years of study we recorded 24 cases of dead lynxes (Table 2). The main cause of mortality in this period was accidental illegal trapping in coil-spring traps and snares set to catch foxes and rabbits. At least eight individuals were killed in this way, of which four had been radio-tagged (AMR = 015). A female lynx with kittens was killed by a poacher with hunting dogs. The second most important cause of mortality was road traffic (AMR = 006). Five lynxes were killed by cars on road C-445, which runs along the western limit of the National Park, crossing lynx habitats. At least three lynxes drowned in artesian wells (12.5%, the first of these radio-tagged; after discovering it, we looked in other wells in the area and found two more). Four individuals were found dead from unknown causes (167%). Another lynx was caught alive by men and probably died of stress (the 'accident' in Table 2). Two adult females died of starvation due to natural causes. One was radio-collared and was lame through arthrosis, while the other had two broken ribs probably due to being kicked by a red deer *Cervus elaphus*. Evidence of prey-caused mortality in wolves *Canis lupus* is given in Mech and Nelson (1990).

DISCUSSION

The AMR of the Doñana lynx population is high, and similar to the mortality of some harvested

bobcat *Felis rufus* populations (e.g. Fuller *et al.*, 1985). This suggests that being categorized as an endangered species (IUCN, 1988), protected by Spanish law, and occurring in protected areas, does not guarantee the conservation of this feud.

Most lynx mortality in Doñana is caused by accidents related to human activities, with about 75% of the AMR either directly (illegal trapping, road accidents, hunting with dogs) or indirectly (drowning in artesian wells) man-caused. This is a consequence of the high humanization of the area surrounding the National Park (a similar case is described by Mech (1989) for the wolf). Though illegal, the use of coil traps and snares to kill rabbits and foxes in many private properties bordering the National Park (mostly agricultural land) is common. Road traffic is also very high, especially in summer, because of intensive coastal tourism.

Inter-annual variations in mortality rates could be caused by changes in rabbit availability, as rabbits are the staple prey of Iberian lynx (Delibes, 1980), and rabbit breeding depends on weather conditions (Soriguer, 1981; Vandewalle, 1989). Scarcity of rabbits must favour lynx dispersal and then increase mortality rates. However, at present we are not able to demonstrate a cause—effect relationship between rabbit numbers and lynx mortality.

Fragmentation increases the number and length of edges (Laurence & Yensen, 1991) and is associated with increased mortality risk to lynxes. The risk of living in the surrounding area is shown when the mortality rate of adult resident males (0.48, $n = 566$ radio-transmitter days) in The Acebuche (a protected property by the western side of the Park bordered by the C-445 road) is compared with the mortality rate of adult males living in the Biological Reserve, in the middle of the park (0.00, $n = 2225$ radio-transmitter days).

Fragmentation of good-quality habitats also explains the high mortality of dispersers, which are forced to cross high-risk habitats when looking for new areas to settle. It is interesting to note that females, which have shorter and more delayed dispersal movements than males (authors, unpublished data), have lower mortality rates than males, although this difference is not significant.

As noted, we have not radio-tagged individuals under five months of age. Hence, we do not know mortality rates of kittens under this age, although for some similar species, such as *Felis lynx*, this time is very critical (Kaczensky, 1990). We have only two records of dead lynx under five months old: one died of unknown causes, while the other was illegally trapped. Also field behaviour (activity movement patterns) of some radio-tagged lactating females seems to indicate high neonatal mortality (authors, unpublished data). On the contrary, mortality in predispersing individuals more than five months old is very low.

Based on radio-tracking data and anecdotal records of reproduction, we can speculate about birth rates and evaluate the extreme values of the annual balance of the Doñana lynx population, assuming it to be isolated (Palomares *et al.*, 1991; Rodriguez & Delibes, 1992, this issue). We assume a mean population size of 45 individuals (40–50, according to the cited authors), with 10–13 reproductive females. Female productivity will depend on food availability and other factors (diseases, predators, hazards), and will never exceed two young reaching five months of age per female per year. Using our estimated mean annual mortality rate from the radio-tagged sample (AMR037), the net annual increase will rarely reach nine individuals per year (the difference between the maximum total recruitment, $13 \times 2 = 26$ five month-old kittens, and the estimated number of deaths, $45 \times 0.37 = 16.7$). However, in unfavourable years for breeding (when few or no females are able to breed or kitten mortality is very high), the population could lose 17 lynxes (the mean number of annual deaths), a third of its total number. These simple calculations suggest a pessimistic future for the Doñana lynx population, because the number of individuals lost in unfavourable years exceeds the potential increase in optimal ones.

Total protection of the lynx range in Doñana does not ensure the survival of the population. Some years ago, Dasmann (1983) stated that 'areas designated for nature conservation . . . surrounded by lands used intensively . . . may be in-

adequate to provide for the survival of the species originally contained within them'. Our study corroborates this point of view and provides quantitative information to analyse the relationship between fragmentation, size and shape of a protected area, and mortality of a top predator. At Doñana, lynx are not being hunted toward extermination as happened in the past with *Felis lynx* in Central Europe (Eiberle, 1972). Rather, they are dying because of diverse human activities which are not directed against them (illegal trapping focused on foxes and rabbits). Most deaths occur during dispersal, when lynx cross the limits of the protected area. Conservation of biodiversity in the Doñana National Park, as illustrated in this case study of the Iberian lynx, requires a policy of nature and wildlife conservation throughout the region, not only inside the protected area, which is too small to hold a minimum viable population of the species (Shaffer & Samson, 1985; Palomares *et al.*, 1991). The recent creation of the Natural Park of the Doñana Surroundings is a necessary, but still insufficient, step forward.

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