Eur J Wildl Res (2010) 56:633–640
DOI 10.1007/s10344-009-0353-5

ORIGINAL PAPER

# Factors conditioning the camera-trapping efficiency for the Iberian lynx (*Lynx pardinus*)

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Received: 29 December 2008 / Revised: 25 November 2009 / Accepted: 2 December 2009 / Published online: 9 January 2010


**Abstract** Camera trapping is the most used method for surveying medium-sized carnivores in Spain. The main target for these surveys has been the Iberian lynx, the most endangered cat in the world. The Iberian lynx conservation program has received the largest EU LIFE projects grant. So, efficiency is a key goal for managing this grant. During 2003 and 2007, we have applied these funds to the survey of the Iberian lynx in Eastern Sierra Morena (Spain). Using two different techniques, we have studied both to see which is the most efficient. The survey developed in active latrines resulted more efficient than that of scent stations and live prey camera trapping throughout the years, although there has been a variation between years. Otherwise, the live prey method has been the one providing the greatest speed and number of pictures per entrance. We suggest that camera-trapping surveys can be improved in terms of efficiency for a wide range of species, or at least for the Iberian lynx. To improve the results, cameras might be placed in relation to breeding territories. With this determinant, camera-trapping surveys would be shorter than 120 days. Finally, we suggest how those surveys for medium carnivores should be designed.

**Keywords** *Lynx pardinus* · Camera trapping · Wildlife management · Carnivores

Communicated by H. Kierdorf

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## Introduction

The Iberian lynx is the most threatened feline species worldwide (Nowell 2002). It is also an Iberian endemism (Johnson and O'Brien 1997). Reproduction during the last decade has only been recorded in two sites within its historic distribution area (Rodriguez and Delibes 2003): Doñana and Sierra Morena (Guzman et al. 2004). Over the last few years, its monitoring has been mostly implemented by camera trapping. This technique is based on automatically shot photos that the animals set off through a sensor connected to the camera. This technique was first developed during the early 1990s for following species of mammals in the Amazon rain forest (Griffiths and Van Schaick 1993). Because it allows the continual tracking of different species in a low invasive and interfering manner, its use has widened (Rowcliff and Carbone 2008). A review of the use of this technique until the late 1990s can be found in Cutler and Swann (1999).

Furthermore, with the complementary use of camera identification techniques, camera trapping enables the detailed monitoring of any population. For highly threatened species such as the Iberian lynx, the individualized identification of specimens is crucial. Thus, we are able to calculate the real population size and monitor the survival of any individual through time (Simon 2008). As with other felines (Sunquist and Sunquist 2002; Heilbrun et al. 2003), the unique lynx fur characteristics allow this individualization as each specimen preserves its unique fur pattern during its entire life.

The first trials with the Iberian lynx were undertaken during the spring of 1999 in Doñana (Redondo et al. 2002) and subsequently, that same year, in Sierra Morena and Montes de Toledo (Guzman et al. 2004). Currently, most of the information used for the management of the Iberian lynx is obtained by camera trapping (Guzman et al. 2004).

There are many factors that might be affecting Iberian lynx behavior and, therefore, their activity, movement range, and probably their response to camera traps. Temperature, photoperiod, rainfall, evaporation, barometric pressure, and even the phase of the moon have been demonstrated as basic in their lives (Beltran and Delibes 1994). These factors can be considered as extrinsic, not directly related to the method used nor to the individuals (age, gender, etc.). The objective of the present study is to provide information about the intrinsic factors that condition the efficiency of camera trapping in the case of the Iberian lynx. We study factors directly related to the method used and to the lynx individuals trapped. Efficiency is understood as the ability to achieve the best results with minimal effort and is defined by two different estimates. This study is a consequence of the intensive follow-up carried out over a 5-year period (2003–2007) with the Iberian lynx in Spain, but the results obtained using camera trapping as a follow-up method can be applied to other species in other areas.

## Materials and methods

The work was realized from 2003 to 2007 on four large private estates (ranging from 985 to 3.215 ha) in the Eastern Sierra Morena. Biogeographically, this area is part of the western Mediterranean sub-region or, more precisely, of the western Mediterranean Iberian province, in the Luso–Extremadurense sector (Rivas-Martínez et al. 2004). This area, characterized by the Mediterranean climate, has a clear summer drought, characterized by the highest temperatures, most rainfall in autumn and spring, and mild temperatures in winter (MMA 2002).

The greater part of the area considered in the study is in the granitic area of *Los Pedroches* (Vera 2004). In most of the study area, this granitic condition has produced an undulating topography lacking in outstanding slopes. The soils generated are acidic, nutrient-poor, loose, and easily burrowed, and thus represent an advantage for rabbits (Villafuerte et al. 1995). In most part of the studied area, there is a mosaic of closely wooded areas, cleared pasture areas, *mancha*, and others. This mosaic provides an advantage as much for the rabbits as for the lynx, because it supplies both refuge and feeding areas, allowing the existence of both species (Lombardi et al. 2003; Palomares et al. 2001). The estates are used for big game hunting and, in some cases, grazing of livestock and small game hunting as secondary usage. Generally, this use is of low intensity as nearly all activity is limited to certain days a year (big game, Gonzalez and San Miguel 2005). Therefore, these areas have the tranquility necessary for the preservation of the Iberian lynx and other feline species (Haines et al. 2006).

During the course of our study, the population density of the lynx changed on these estates, as some of these were occupied by new members during that time. At the end of the study, in 2007, all the estates had breeding female territories, ranging from one to five territories per estate and year (Fundación CBD-Habitat 2006; Gil-Sánchez 2006).

In order to estimate the existing lynx population and its evolution in the study area, cameras were positioned with a uniform geographic distribution, approximately one for every 100 ha. The hunting area of an adult female (possible breeder) is known to have a core area of approximately 300 ha (Palomares et al. 2001); therefore, the study was designed using three to five cameras in each area. The camera locations varied during the experiment but were constant within the year. The variations corresponded to the previous year's results. The study was carried out between May and November from 2003 to 2007.

In order to increase the possibility of detecting lynx, both visual and scent lures have been employed, and cameras have been placed in known marking spots—latrines (Robinson and Delibes 1988). The use of lures invites the approximation to the camera of an individual of the target species to activate the sensors (by foot pressure, volume, or heat). In our case, the scent lure used was female lynx urine, obtained from animals of the captive breeding program (MMA 2004). The effectiveness of this substance instead of other similar commercial products was proven in Doñana National Park (Redondo et al. 2002). Lynx are also easily seduced by visual incentives (Ruggiero et al. 1999). For Iberian lynx camera trapping, the visual incentives are visible but out of reach, consisting of live prey (in cages), usually domestic pigeons. Both analogical and digital cameras can be used for camera trapping. Analogical cameras were used mainly because of their commercial availability. Guzman et al. (2004) have described in detail their characteristics and operation. In this study, camera trapping was implemented mostly with live prey and scent lures. The infrared equipment used was all digital, activated through a passive infrared sensor, and employed basically in lynx latrines.

After the picture is taken, the animal is identified using the characteristic spots on its fur. Since 1999, a centralized photo-identification catalog of the Iberian lynx has been kept (Guzman et al. 2004). This identification uses mostly the lateral region and paws as these spots experience the smallest distortion with motion. With these pictures, gender (genitalia) and age (body size, beard and brush size, facial characteristics, etc.; García-Perea 1996) can be assigned to each specimen. Thus, it is possible to distinguish between a cub, a young adult (>1 year), and a territorial adult (Ferreras et al. 2004).

The main prey of the Iberian lynx is wild rabbit (Delibes 1980). In order to determine its absolute abundance, rabbit census were conducted along with camera trapping. The method provided by Palomares (2001) was used. This methodology consists of walking transects of 1–2 km in length, at dusk or dawn, at least three times, during their maximum abundance period (Beltran 1991). Every rabbit within a 10-m strip is counted. Then, the absolute number of rabbits per hectare is determined through a formula. So, in each estate, a transect net with homogeneous habitat units was set up. The number of transects per estate was not constant ($n$=6–16) because a transect was drawn up for every 150–200 ha per estate.

We developed four different analyses, one for each of the four variables considered: number of pictures per entry, response time, and two measures of efficiency. An "entry" was defined as every time one or more serial pictures of a lynx were taken with the same camera during the same day. Every entry is charted by the precise animal, number of pictures taken, and date. The number of pictures per entry is a very important parameter because, as the lynx dot pattern is complex and different in each body side, more than one picture of the same individual in the same entry are needed to have each individual completely identified. The response time was defined as the number of days that the camera was active before the first lynx entry. Its purpose is to reflect the time needed to obtain lynx pictures in different conditions. Finally, and due to the huge effort invested in the follow-up of each lynx, the evaluation of the efficiency of camera trapping as referred to a unit of effort becomes indispensable.

For each of the response variables, number of pictures and response time, an analysis of variance with five fixed factors (ANOVA, sum of squares type III; Quinn and Keough 2002) was carried out. The factors considered are described in Table 1. The Tukey honestly significant difference (HSD) test has been used for realizing several cross tabulations.

In the present study, we considered the night trap (NT) as the effort unit, according to Jackson et al. (2005). The camera effort is the number of days it is active in the field. In order to determine the factors affecting camera efficiency, two different camera efficiency indicators were defined (Jackson et al. 2005):

- Indicator 1: relationship between number of entries and effort, measured as 100 traps/night
- Indicator 2: relationship between number of different animals trapped with camera and effort used, measured as 100 traps/night

The analyses carried out were similar to those in other studies of trap efficiency (Carbone et al. 2001; Muñoz-Igualada et al. 2008). In our case, the sampling unit considered was the camera trap. Every camera trap was characterized by several factors (Table 1). In order to explain both efficiency indicators, an analysis was carried out using a univariant mixed effect model, with a random effects factor (estate), two fixed-effects factors (year and lure), and a covariant (rabbit abundance). The method used for calculation is the sum of squares type III (Quinn and Keough 2002). We considered the abundance of rabbits around the cameras because it can modify the lynx's trappability as the rabbits are their main prey. When there was a transect within a 250-m radius around a camera, the rabbit density in it was assigned to that camera. If there were many transects, the density assigned was the mean. We chose this radius because it is slightly higher than the average daily distance traveled by a rabbit (Lombardi et al. 2003, 2007).

**Table 1** Elements of entry analysis

| Factor | Factor level | Description |
|---|---|---|
| Gender | Male<br>Female | Gender of lynx making the entry |
| Age | Puppy–young | Specimen under 1 year |
| | Dispersive | Specimen in dispersion |
| | Adult | Territorial specimen |
| Year | 2003, 2004, 2005, 2006, or 2007 | Year of campaign |
| Estate | 1, 2, 3, or 4 | Every estate where study is implemented |
| Lure | Urine | Camera with scent appealing substance |
| | Live prey | Camera with living prey |
| | Latrines | Camera in latrines |

Only year, state, and lure were used in the efficiency indicators analysis

All the analyses realized were verified for a normal hypothesis, so a logarithmic transformation of the efficiency and time response indicators is carried out along with a cubic root adjustment of the number of pictures $\left(y = (x+1)^{0.33}\right)$ (Quinn and Keough 2002). Several cross tabulations with the Tukey HSD test have been undertaken. All the statistical tests have been done in Statistica 7.0, with standard probability criteria ($p<0.05$).

## Results

A total of 411 cameras were used for camera trapping, with a total effort of 38,030 NT. During that time, 1,294 entries were obtained and 88 different specimens were identified. All the animals made several entries, between one and 100 ($\bar{x} = 14.739$, SE=18.704). During the 5 years of the study, the effort was not homogeneous over all the years or all the estates in the same year.

The 1,294 entries added up to 6,862 pictures, with a mean of 5.303 pictures per entry (SE=5.534). Two factors were significant in the analysis of pictures per entry: estate ($F_{3,1125}$= 3,171; $p$=0.024<0.05) and type of lure ($F_{3,1125}$=3,580; $p$= 0.028<0.05; see Fig. 1). In that analysis, significant differences have been observed between estates 1 ($\bar{x} = 4.644$, SE=4.95) and 2 ($\bar{x} = 6.199$, SE=5.633; $p$<0.000) and between 1 and 3 ($\bar{x} = 5.619$, SE=5,988; $p$=0.012). As far as to the lures, the live prey ($\bar{x} = 5.504$, SE=5.636) produces a different behavior compared to urine ($\bar{x} = 3.132$, SE= 3.878; $p$=0.005) and camera trapping in latrines ($\bar{x} = 2.176$, SE=1.144; $p$<0.000), where no significant differences were observed when comparing them ($p$=0.825). The working model explains 16% of the total variability ($R^2$=0.16).

The response time varied widely between cameras ($\bar{x} = 60.861$; SE=41.964). The following factors resulted as significant in that analysis: year ($F_{4,1125}$=7.558; $p$<0.000); lure ($F_{2,1125}$=11.963; $p$=0.028<0.05); and the interactions between estate and year ($F_{10,1125}$=3.44; $p$<0.000); year and age ($F_{8,1125}$=3.313; $p$=0.001); estate, year, and age ($F_{15,1125}$= 2.938; $p$=0.002); estate and lure ($F_{2,1125}$=3.219; $p$=0.04); year and lure ($F_{5,1125}$=2.481; $p$=0.03); and estate, age, and gender ($F_{9,1125}$=3.337; $p$=0.009). The model explained 33.4% of the variability ($R^2$=0.334). Significant differences have been observed between estates 1 ($\bar{x} = 62.5$, SE=42.133) and 2 ($\bar{x} = 32.03$, SE=23.456; $p$<0.000). Referring to the lures, differences have been observed between live prey ($\bar{x} = 62.5$, SE=42.133) and the others ($p$<0.000; for urine $\bar{x} = 32.03$, SE=23.456; for marking places $\bar{x} = 43.57$, SE= 37.182), with no differences among these ($p$=0.762).

When analyzing efficiency estimator 1 (relationship between number of entries and effort, measured as 100 NT), we only observed one statistically significant difference: the type of lure ($F_{2,299}$=7.193; $p$=0.0484<0.05). The model explained 34.887% of the variability observed in estimator 1. Every year, the lure with better response for indicator 1 was camera trapping in marking spots ($\bar{x} = 3.653$, SE= 6.597), followed by live prey ($\bar{x} = 2.964$, SE=3.756) where no significant differences were observed ($p$=0.252) and urine ($\bar{x} = 0.769$, SE=2.141) with significant differences ($p$= 0.018). Significant differences were also observed when comparing urine and live prey ($p$<0.000).

In respect to indicator 2 (relation between number of different specimens camera-trapped and effort invested,

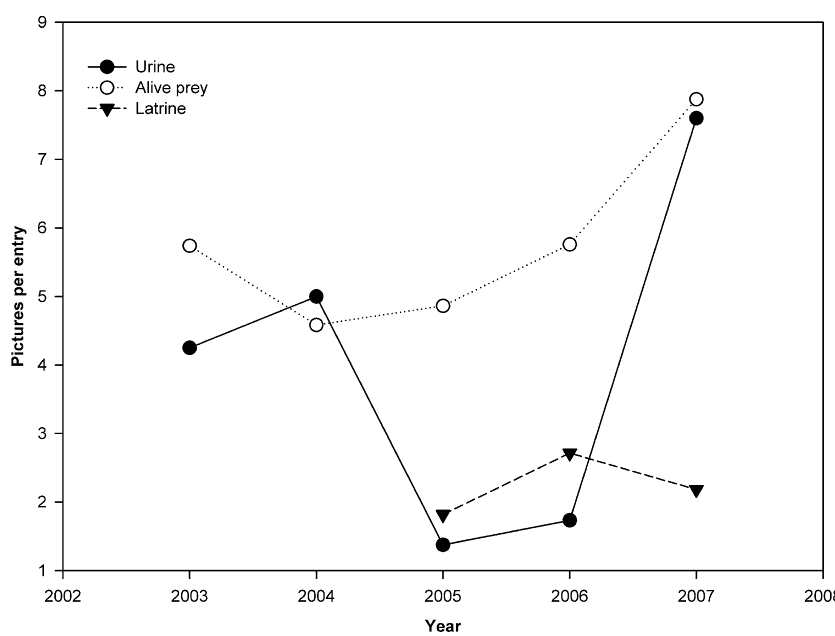



**Fig. 1** Time evolution of the number of pictures per entry according to type of lure

measured as 100 traps/night), both lure ($F_{2,299}$=8.477; $p$=0.0003) and year ($F_{4,299}$=3.620; $p$=0.0115) were significant (Fig. 2). The model explained up to 30.385% of the variability observed by the estimator. The highest indicator in this case as in the previous one was given by camera trapping in marking spots ($x$=2.538, SE=4.221), followed by live prey ($\overline{x} = 1.364$, SE=1.803) where significant differences were observed ($p$<0.000) and by urine ($\overline{x} = 0.894$, SE=2.679) where differences were also seen ($p$=0.018). In respect to the year, the highest values were obtained during 2006 ($\overline{x} = 2.766$, SE=3.383) and the lowest in 2004 ($\overline{x} = 0.662$, SE=1.189; Fig. 2). There were significant differences between 2003 ($\overline{x} = 1.136$, SE=1.436) and 2006 ($p$=0.002), 2004 and 2006 ($p$<0.000), 2004 and 2007 ($\overline{x} = 1.494$, SE=2.191; $p$=0.003), and 2005 ($\overline{x} = 1.263$, SE=2.336) and 2006 ($p$<0.000).

## Discussion

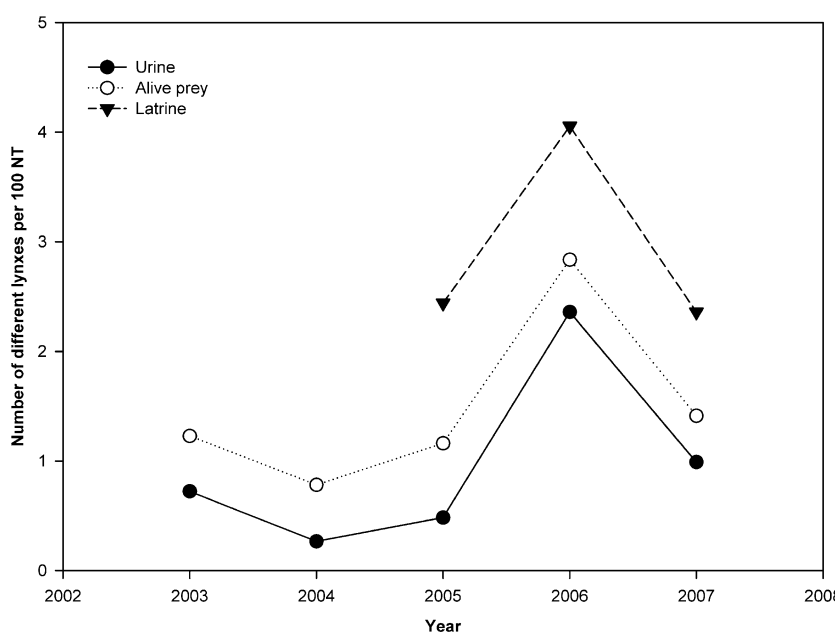
The present study reveals that there are varying ways in which lynx react to different stimuli (visual, olfactory, territorial). Therefore, better camera-trapping results can be obtained using different lures, though part of the differences may be due to the use of different camera types (Kelly and Holub 2008). Differences registered between camera trapping in the latrines and other methods may be assigned both to the camera-trapping effort used and the intrinsic differences in the methods.

Some of the differences found in efficiency can be due to surrounding conditions. So, the use of cameras with scent as lure was less efficient. The present field work was carried out in areas with high average temperature; this may have led to a decrease in the efficiency of the lures due to their volatility, as has been observed with other species where response to scents is season dependent (Hayes et al. 2006). We did not carry out a specific analysis by month because part of the temperature effect might have been concealed by the lynx's cycle, especially concerning the cub development (Fernandez et al. 2002). However, this factor might be considered in further studies.

The time response and number of pictures by entry demonstrate a high variability. The different number of pictures by entry depending on the lure was, as with efficiency, an anticipated result. The difference between estates may be due to an unequal distribution of lynx. The difference in rabbit density, together with the unequal distribution of reproductive females, explains the variance in occupation of the territory by different age groups (Palomares et al. 2001). Thus, in areas with less prey abundance, as happened in estate 2, lynx will pay more attention to the appearance of a potential prey.

Different causes may be responsible for the variations observed in time elapsed between entries to the cameras. The inter-annual differences may be due to different weather conditions that determine rabbit abundance (Beltran 1991). As the abundance of rabbits differs according to habitat (Lombardi et al. 2003; Palomares et al. 2000), this variability may explain the estate–year interaction. The year–age interaction may be explained through the variability in birthing years of the cubs (Fernandez et al. 2002) and the inter-annual and spatial fluctuations in lynx productivity, which is linked to the rabbit fluctuations (Palomares et al. 2001). This factor may also explain the estate–age–gender interactions.

**Fig. 2** Time evolution of indicator 2, by type of lure



In reference to both efficiency estimators, the type of camera trapping implemented is a statistically significant factor. The differences observed allow the possibility of separately regarding each type of lure. When the surveys of these species are presented, this fact achieves relevance. For both indicators 1 and 2, a small percentage of variability has been explained. Part of the variability may be attributed, among other things, to individual behavior (Wegge et al. 2004), to the physical environment (Kelly and Holub 2008), to the specimen density (Carbone et al. 2001), to the human pressure they face, or to their exposure to the cameras.

The variability observed for indicator 2 may be caused by the variability in the effort carried out in association with the year factor. Observing the time evolution of the estimator for the different lures (Fig. 2), we obtain a pattern slightly inversely proportional to the effort evolution in contrast with Wegge et al. (2004). Part of the existing variability, especially the increase observed during 2004 and 2005, cannot be explained by a decrease in the camera-trapping intensity. Likewise, the dramatic decrease during 2003 and 2004 (63% for urine and nearly 36.2% for live prey) cannot be explained only by the 20% increase in the camera-trapping effort. Another possible explanation is based on learning both by the lynx and by follow-up staff. The learning ability of felines is very high (Sunquist and Sunquist 2002). Therefore, it seems logical that they learn not to respond to stimuli that do not provide a benefit. Consequently, the experience with the camera may place restraints on their response to that camera. On the other hand, the follow-up staff improves in the placing of camera-trapping equipment, and once the specimen catalog is available, a lower number of entries and pictures are required to properly identify the animals.

None of the efficiency estimators recorded differences between estates, despite the use of different observers (Kery and Schmidt 2004). This may be explained by the low level of interaction between observer and animals, an intrinsic characteristic of camera trapping. So, the conclusions obtained in this study may be applied in the follow-up studies of lynx in their remaining distribution area.

Considering the average length of the campaigns implemented, it may be convenient to carry out a smaller effort mainly in the last part of the season. Apparently, lynx, in contrast with other species (Wegge et al. 2004), are not frightened by camera flash, but further research is needed. As mentioned before, it seems that they learn not to answer to the stimuli provided in view of the lack of benefit. When assimilating new technologies in the follow-up, this is an important fact that must be taken into account.

The present work intends to expose contrasted results for the improvement of the camera-trapping technique, following previous studies (Zielinski and Kucera 1995). In the camera-trapping campaigns for the reproduction follow-up, a greater part of the effort should be focused both upon cameras with live prey and infrared, preferably the latter. Live prey cameras provide high efficiency and acceptable response time.

An interesting option is camera trapping in lynx's marking points using passive infrared sensor equipment,

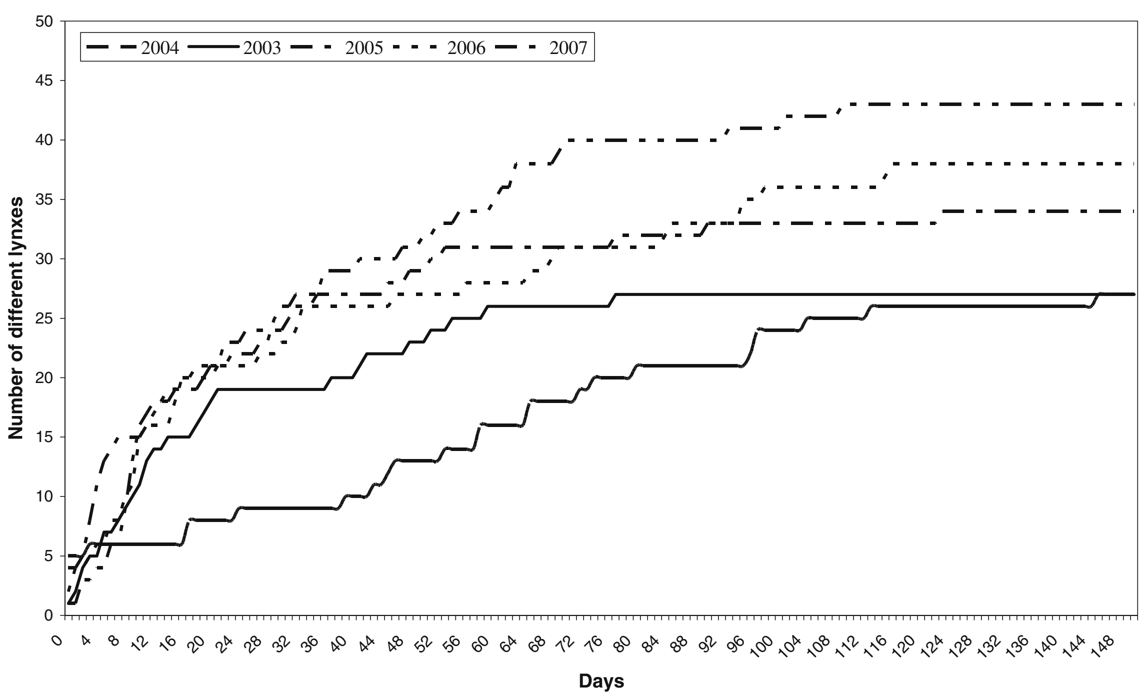



**Fig. 3** Accumulation curve for the number of different lynx camera-trapped per year

though other considerations are needed. For the different camera-trapping equipment commercially available, some general comments are that most of the cameras tested work deficiently under extreme weather conditions (temperatures above 35°C or under −5°C). High temperatures cause a lot of blank pictures, reducing battery lifetime. According to actual visiting schedule (less than a week for every camera trap), this situation causes more identification work. A possible improvement could be the adding of complementary external sensors. In this way, one of the most frequent errors, an often long response time, could be avoided. Many of these equipment are not provided with the possibility of regulating flash intensity, and this may cause the non-detection of some lynx (Wegge et al. 2004). Also, an interesting improvement would be the use of infrared night lighting technology.

In relation to the spatial distribution of marking points, two different situations are considered. In areas with stable lynx occupation with defined territories, our experience recommends placing two to three cameras per territory, with live prey and at least one camera in the prevalent marking points. This will probably lead to better results than those obtained in the present study while maintaining the camera traps per territory. In peripheral areas, or areas not well known enough, one camera should be placed for every 100 ha, maintaining the effort per hectare developed during this study.

As far as the length of campaigns, 90 days seems a manageable time frame. As the objective of the analyzed campaigns is the general follow-up and the detection of cubs, the different specimens become especially relevant. As the birth time of cubs is concentrated between March and April, and it takes normally 2 months for them to leave the lair (Fernandez et al. 2002), a small delay in the beginning of the campaign, until early July, seems reasonable. So, we would be able to guarantee that cubs have left the lair and can be photographed when campaign starts. On the other hand, the length of the campaign can be limited to a maximum of 120 days, as efforts above this time have nearly no relevance in as much as detected animals. During this study, all the detected lynx were camera-trapped before the 120th day, except for 2006, as shown in Fig. 3.

**Acknowledgments** The present study has been carried out in the framework of the LIFE-Nature projects 02/NAT/E/8609 and 06/NAT/E/000209. We also extend our gratitude to the Spanish Ministry of the Environment for providing funds to the Fundación CBD-Habitat. We wish to thank the owners of the private estates for their cooperation, past and present, in the preservation of the Iberian lynx. Also, we express our gratitude to Samuel Pla, Francisco Sánchez, Manuel Mata, and Francisco Leiva for their help with the hard work and their advice during the project as well as to the rest of the CBD-Habitat team for their varied contributions. Thanks to María del Mar Celada for her help with the translation. Alfonso San Miguel and María Martínez-Jaúregui helped with the data management and earlier discussion. Thanks to the personnel working in the lynx reproduction in captivity plan for providing urine. Thanks to the Consejería de Medio Ambiente and EGMASA teams of the Junta de Andalucía with whom the project was developed. We are also thankful for the continuous support of the Fundació Territori i Paisatge of the Obra Social de Caixa Catalunya. Comments from Luis Mariano González and two anonymous referees seriously improved the manuscript.

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