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Use of Camera Trapping in Determining Iberian Lynx Population Parameters: The Use Area and Its Limitations

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Abstract
Below are the results of the survey of the Iberian lynx obtained with camera-trapping between 2000 and 2007 in Sierra Morena. Two very important aspects of camera-trapping concerning its efficiency are also analyzed. The first is the evolution along years according to the camera-trapping type used of two efficiency indicators. The results obtained demonstrate that the most efficient lure is rabbit, though it is the less proven (92 trap-nights), followed by camera-trapping in the most frequent marking places (latrines). And, we propose as a novel the concept of use area as a spatial reference unit for the camera-trapping monitoring of non radio-marked animals is proposed, and its validity discussed.

Introduction

The Iberian lynx is the world most threatened felid [1]. Since more than a decade ago, when IUCN considered it critically endangered [2], efforts devoted to its preservation have notably increased. The first step for the Lynx preservation is a precise knowledge of its population status. In order to achieve this target, in Spain a national census was undertaken between 2000 and 2002. The mentioned census, using different methods, obtained a result of less than 200 animals [3].

Camera-trapping has been the most used method in order to precisely determine population size. The technique is based in taking automatically pictures of different specimens. The system was first developed for mammal monitoring in tropical forests [4]. As spotted felines have a unique fur pattern, animals can be identified using the mentioned patterns [5]. This technique is known as photo-identification and together with camera-trapping allows an estimation of different population and habitat use parameters [6,7].

In the case of the Iberian lynx, camera-trapping was first used in the Doñana National Park, in 1998 [8]. Since 2000 , it has been used in a comprehensive way in the historical distribution area to achieve a national census [9]. The following resultswere obtained from different studies implemented by the Fundación CBD-Habitat, in the framework of national census (2000-2002, [3]) and its development until nowadays. The objective is to determine the efficiency of the different methods used as well as the evolution of results in time.

Besides, one of the main problems when managing territorial animals without marking them is the ignorance of their territory. In the present work an alternative method is proposed, given the stability observed in used-areas.

Material and methods

Study area

Studies have been implemented in Sierra Morena Oriental, in the municipality of Andújar (Jaén) , in four private estates. The mentioned area is included in the Iberian western Mediterranean province, part of the Mediterranean western sub-region [10]. This area, characterized by Mediterranean climate, has a marked summer drought period that coincides with the highest temperature period, and rainfall mainly in spring or autumn, and winter with relatively mild temperature [11].
The greater part of the study area belongs to the granitic area of los Pedroches [12]. This type of soil is responsible for the undulating topography of most part of the study area. The soils generated are acidic, nutrient-poor, loose and easy to dig in, thus representing an advantage for wild rabbit (*Oryctolagus cuniculus* L. 1824; [13]). Natural vegetation has been clearly modified. In most cases, the study area presents a mosaic of closely wooded areas, pasture areas, bush areas and others. This mosaic provides benefits for lynx and rabbit, its main prey, and allows the existence of both [14,15].
The total study area is of 7,075 hectare, divided in four private estates, from 985 to 3,215 hectares. The main land use of these estates is big game hunting, with livestock grazing and small game hunting (partridge with birdcall) as secondary land use. This activity is of low intensity as it is limited to certain days a year, as hunting is restricted to big game.

Camera-trapping methodology

Information is gathered through campaigns. Those campaigns consist in a simultaneously activated net of camera traps within one state and with one common goal. The camera-trapping equipment is composed of a camera and a presence detector. It is located in a geo-referenced site, through Garmin Geko 201 GPS designated as camera-trapping station. All these stations form a sampling point net, increased every year, though same stations may be used in different years. Mean distance between stations was 2,021 m (±1,254 m).
The cameras used are digital (different models of Stealth Cam®) and 35 mm compact analogical (for a more detailed description, see Guzmán et al. [3]). Cameras were activated using weight sensor (analogical) or passive infrared rays (digital). Weight sensor is a 25x25 cm. metal sheet, connected with the camera, activated by foot pressure. Passive infrared rays work as thermic-volumetric changes detectors, and shoot a picture when an animal enters their activity range (2-8 m) and activates the system. All the equipments used are provided with a device that marks the date on the picture. The digital cameras also print time.
In order to increase the possibility of detecting lynx, several lures have been used such as lynx urine, domestic pigeon Columba livia L. 1758 and rabbit, both of them alive. In Guzmán et al. [3] it can be found a more detailed description of camera trapping managing with special attention to camera-trapping with urine. Camera-trapping with pigeon started in 2002. Rabbit has been used only during the 2006-2007 season and for short time periods (from 18-22 days), using one station per use

area. The use areas are defined by the minimum convex polygon (MCP) determined by the camera-trapping stations where a picture of reproductive female is obtained during the same year. For the marking points with faeces (latrines) the cameras used in camera-trapping were provided with infrared sensor.

Regarding the time/ space sampling management (intensity, stations density, campaign length) two different stages may be distinguised: 2000-2003 and 2003-2007. At the beginning of the study, the information referring to lynx presence derives from indirect signs (mainly latrines, trails, quotations and observations). So, the main objective of campaigns developed between 2000– 2003 was focused on identifying stable presence areas, plus gathering demographic population data. Sampling was implemented during campaigns of about three months covering progressively all the area during all year, with 14.44 to 16 ($\bar{x} = 471.92 \pm 444.7$) trap-nights per campaign. Lynx urine was the lure mainly used. Those campaigns were part of the national Iberian lynx census [3].

From the spring of 2003, an intensive campaign and several additional campaigns are implemented every year. The main goals of intensive campaigns are censing (range of age, individual characterization), detecting of yearly reproduction and inter annual cub survival, defining adult specimen use areas and determining dispersive movements. They are also helpful to detect pathologies as well as undernourished or injured animals. They are carried out around the whole study area, from early spring until autumn, (length ranging from 90 to 184 days; $\bar{x} = 156.14$; SD = 20.67), density is one station/ km^2 and trapping effort is similar in different female Iberian lynx use areas (2 to 4 stations per area) and variable within states ($\bar{x} = 826.82$; SD = 813.98 trap-nights per campaign). These variations are due to the different values in use areas per state and year.

Additional campaigns have also been run following very precise objectives, such as following a large litter, control of undernourished or injured animals, consolidation of the knowledge of a certain area etc. On the other hand, additional campaigns are somewhat shorter (31-138 days; $\bar{x} = 84.27$; SD = 48.98), developing season may vary and have no defined camera trapping effort (99-600 trap-nights; $\bar{x} = 365.58$; SD = 199.43).

Photo identification

Each specimen camera- trapped is characterized by its unique dotted fur. Every animal has lifelong an individual dot scheme, as other felines [16]. Individualization is determined by side and paw dot pattern, where movement deformations are smaller. In order to identify them correctly, many pictures are necessary, because lynx dot pattern is different in each side, so pictures of both sides are needed to identify and file each specimen.

Each animal receives age and gender assignment. Genitalia characterization determines sexing. Aging is less precise, enough pictures are needed, and it is based on animals' face look, whisker size and ear brushes, allowing an estimation of age [17]. There are three aging categories distinguished: cub, territorial adult and one category containing sub-adults and non-territorial adults (as demonstrated by camera-trapping).

Use areas determination

The reproductive female use areas are the territorial units used for monitoring. The use areas are defined by the minimum convex polygon (MCP) determined by the camera-trapping stations where a picture of each reproductive female is obtained during a year. As territory they are stable in time [15]. In order to determine MCPs each camera-trapping station is geo-referenced, and MCPs are developed using Animal Movements 2.0. extension for ArcView 3.1. [18].

Data registration

A capture event is when a lynx appears in one o more pictures, taken on the same day and under the same light conditions. The same capture event may contain one or more pictures of the same animal, depending on the time the specimen stays in the station. In each capture event only one animal is considered for the analysis, though frequently in the same picture there are more than one animal, e.g. mother with cubs. When the capture event gathers more than one animal, only the oldest specimen is considered for the analysis [19].

Use of efficiency indicators

The evaluation of camera-trapping has been implemented referring to an effort unit. According to Jackson et al. [20], effort unit used in the present study is defined by trap-night (TN). To determine the effort corresponding to any campaign, the figure is obtained by counting the total number of whole days when all the cameras were actively working. If we define necessary effort as trap-night, we obtain two basic efficiency indicators [20]:

Indicator 1: relationship between the number of entries and effort, measured in 100 trap-nights

Indicator 2: relationship between the number of different animals trapped with camera and effort done, measured in 100 trap-nights

Statistical analysis

The present study is based on descriptive statistics, despite more specific analysis have been developed for specific aspects. Averages and standard deviation of some values are presented, (average = $\bar{x}$ and standard deviation = SD). Statistical data have been obtained using Excel 2003.

A non parametric analysis is performed to verify use areas stability. This comparison analysis is developed through a sign-rank test for paired values that compares the surfaces occupied by the use areas (obtained through MCPs). In the mentioned analysis data will be gathered biannually, due to its scarcity. Data obtained from 2000-2001 to 2002-2003 are gathered together, because there are very few. For these tests, only the use areas wholly contained within the study area are used. A comparison between the use areas within different periods (2000-2003, 2003-2005 and 2005-2007) is implemented. To compare paired values in each period, Wilcoxon sign-rank test is used for analysis.

Also, a simple regression is carried out between number of different lynxes detected and effort done [21]. Both analyses were conducted with Statistica 7.0. software and a standard probability criteria (p < 0,05).

Results

Camera-trapping

During eight years, a total of 55,726 trap-nights and 54 campaigns were implemented ($\overline{x}$ = 1031.96 trap-nights per campaign; SD = 675.34). Effort has not been constant, it has changed according to stable lynx use areas and equipment and staff availability. The more use areas, more effort was done. Less effort was done if there was less staff available.

Table 1. Total trap-nights (TN) per lure and per year.

	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	Total
Urine	3930	6404	1156	1275	2418	1442	1443	971	19039
Pigeon	-	110	1103	6628	8249	6943	5197	6776	35006
IR	-	76	18	-	299	632	82	480	1587
Rabbit	-	-	-	-	-	-	-	94	94
Total TN	3930	6590	2277	7903	10966	9017	6722	8321	55726
Campaigns	5	7	6	10	9	7	6	4	54

During this period a total of 1,728 lynx capture events have been reported ($\overline{x}$ = 32 capture events per campaign; SD = 31.3). During this period, a total of 115 different animals have been detected ($\overline{x}$ = 4.86 different lynxes per campaign; SD = 5.21), plus some unidentified specimens.

Detected specimens – use area

Partially or wholly included in the study area, 13 different use areas have been detected. 9 use areas are wholly within the study area, the rest are partially or totally known thanks to the cooperation of the other teams working on species survey (Consejería de Medio Ambiente de la Junta de Andalucía, Spanish National Park authorities and Adena-WWF). Please see Table 2.

Reproduction has been registered at least once, in all use areas except for one, number 10. Use areas 5, 7 and 13 are considered “newly created” during the study period, because reproduction has only been recorded during 2006-2007 (5) and 2007-2008 (7 and 13). In table 2 it is shown the number of territorial males and females detected in each use area (%A; means percentage out of 2, male and female), and the number of cubs, sub-adult and adult without a defined use area (J). The percentage is shown on a total of 2 because territorial lynxes (both male and female) do not overlap their territory with other lynxes. In at least two use areas, the presence of a territorial female with an adult daughter has been detected, together with reproduction of both mentioned females within the same use area during , 2006-2007 (6). In use area number 8, between 2002-2003 and 2006-2007, both years included, cooperative breeding was recorded with a young female helping her mother with cub breeding. The same event took place in area number 12, from 2001-2002 to 2006-2007, both years included. In these cases and during the mentioned periods, the number of territorial lynxes is 3.

Table 2. Number of non-territorial (J) and percentage of territorial individuals (%A) detected per use area (U.A.) and per year. Averages values are shown for all the use areas and for those which are completely within the study area.

U.A.	Included in the study area	00-01		01-02		02-03		03-04		04-05		05-06		06-07		07-08	
		J	%A	J	%A	J	%A	J	%A	J	%A	J	%A	J	%A	J	%A
1	Partially	0	50%	2	100%	1	0%	4	50%	1	50%	3	100%	0	50%	4	50%
2	Partially	0	50%	3	50%	3	100%	7	100%	3	100%	4	100%	2	0%	1	0%
3	Partially							1	0%	1	50%	2	0%	0	0%	3	0%
4	Partially			2	0%	0	0%	1	50%	2	0%	4	100%	3	50%	1	50%
5	Wholly											1	100%	3	50%	7	0%
6	Wholly					6	150%	6	100%	7	100%	3	100%	4	150%	2	100%
7	Wholly															5	150%
8	Wholly	1	100%	5	50%	5	100%	5	100%	3	33%	3	66%	6	100%	3	100%
9	Wholly			2	50%	2	0%	6	0%	3	0%	2	100%	4	100%	5	100%
10	Wholly			1	100%	2	100%	4	100%	1	50%	3	100%	5	100%	4	100%
11	Wholly			1	100%	1	100%	2	0%	2	100%	2	50%	4	0%	2	0%
12	Wholly			2	133%	5	66%	6	100%	2	100%	1	133%	5	50%	4	100%
13	Wholly							2	0%	1	50%	1	100%	2	100%	2	50%
Average		0.33 ± 0.47	67% ± 24%	2.25 ± 1.2	73% ± 40%	2.78 ± 1.99	68% ± 52%	4 ± 2.09	55% ± 45%	2.36 ± 1.67	58% ± 37%	2.42 ± 1.04	87% ± 33%	3.46 ± 1.82	63% ± 46%	3.31 ± 1.68	62% ± 49%
Average values for wholly contained use areas		0.67	83%	2.21 ± 1.64	84% ± 36%	3.40 ± 2.07	83% ± 50%	4.38 ± 1.81	57% ± 53%	2.67 ± 2.06	61% ± 39%	2.05 ± 1.93	93% ± 25%	4.05 ± 1.25	79% ± 46%	3.73 ± 1.72	76% ± 51%

In Table 2 the averages of number of sub-adults and non territorial adults and percentage of territorial adults detected in each use area are shown. Values have been calculated for all 13 use areas, (general average), and only for areas wholly included in study area.

Specimens detected / year

Considering the use areas as a all, differences in animals detected per year change dramatically. Numbers increase quickly at first, and then stabilize at around 40 animal per year from 2003-2004 .

Implementing a simple regression between number of different animals detected and effort done, estimated as trap-nights, and considering the results as a whole for each season, we can see a significant relationship and a quite good adjustment ($F_{1,52}$ = 36,818; $p < 0,0000$; R^2 = 42,90%).

Use areas

The use areas that existed at the beginning of the study have been preserved through time, despite new ones have been created. For the periods defined, the surfaces of areas completely included within the study area are listed in table 3.

We have compared surfaces (in hectares) of use areas as paired data during the different periods considered. There are no significant differences between 2000-2003 period and 2003-2005 period ($Z = -0.730$; $p = 0.465$), nor between 2003-2005 and 2005-2007 ($Z = -1.153$; $p = 0.249$).

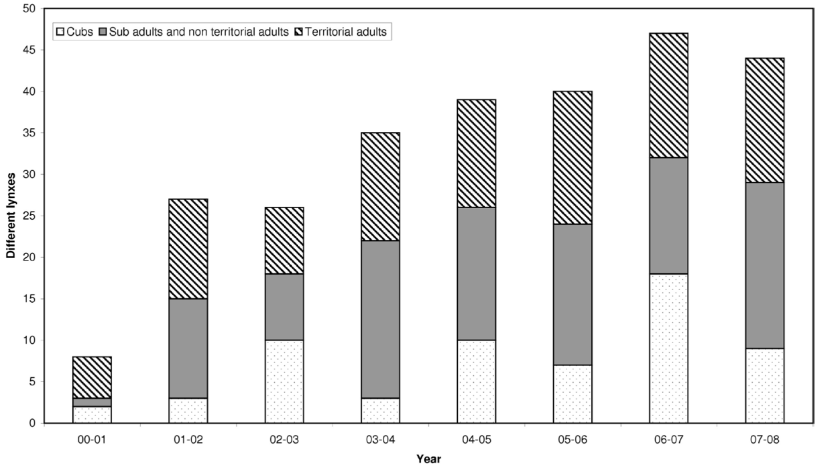

Fig. 1. Different lynxes camera-trapped per year.

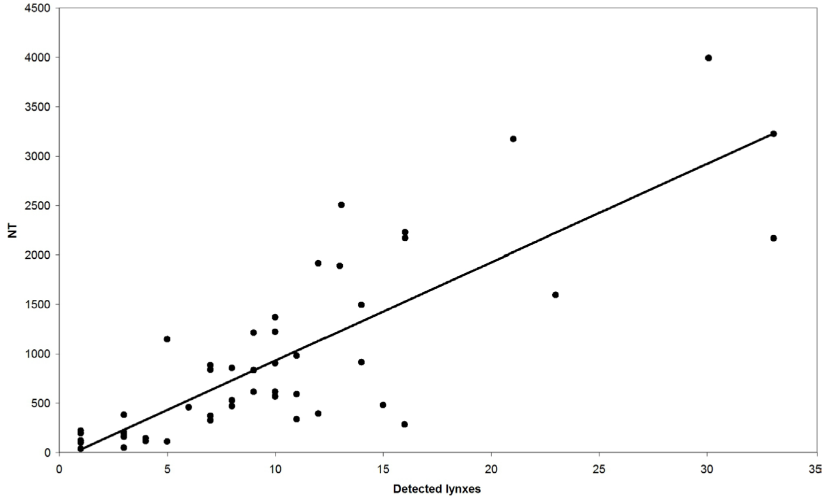

Fig. 2. Relation between detected lynxes and trap-nights (NT).

Table 3. Surface in hectares and territorial females per use areas (U.A.).

	U.A. 6	U.A. 8	U.A. 9	U.A. 10	U.A. 11	U.A. 12	U.A. 13
2000-2003	227.95	183.49	-	-	64.54	227.48	
	Lupe	Nuria. Lorca	Jándula	Sierpe	Boga	Romea. Paloma	
2003-2005	287.53	244.04	92.56	18.49	173.26	145.72	-
	Lupe	Nuria. Lorca	Zurita	Sierpe	Boga	Romea. Paloma	Maqui
2005-2007	917.33	296.87	32.7	69.35	284.98	115.97	178.24
	Lupe. Viki	Lorca	Zurita	Sierpe	Boga. Nava	Romea. Paloma	Maqui
Average	477.60	241.47	62.63	43.92	174.26	163.06	178.24

Efficiency indicators evolution

The efficiency indicators have changed during the years. Different factors may influence animal entry to the stations [22-24]. In Figures 2 and 3 the averages for indicators 1 and 2 are described, respectively, for the different trapping systems used. Average values are calculated per campaign. Variability is always very high.
Due to large differences (n = 3; $\overline{x}$ = 126.89; SD = 54.97) the results obtained using rabbit as lure are not included. A large decrease in the value of indicator 1 can be observed in camera-trapping with domestic pigeon since 2003-2004. Similar remarkable results have obtained with camera-trapping in marking points (IR) stations.
Indicator 2 and indicator 1 have experimented a very similar evolution. Indicator 2 variation is smaller, probably due to smaller data range. As before, camera-trapping data using rabbit as lure are not shown, due to large differences (n = 3; $\overline{x}$ = 20.09; SD = 7.95). As in indicator 1, best results are obtained with camera-trapping in marking points.

Discussion

Camera-trapping is one of best choices for monitoringing mammals such as lynx due to its small interference with target species [5], animal individualizing capability and difficulties associated to their behavioral pattern. Although it is the most used tool for monitoring spotted felines [20,25,26], there are other proposals [27]. Nowadays, it is the most used technique for the monitoring of basic population parameters of the Iberian lynx (distribution and population size; [3]). Though, validity of the data obtained by camera-trapping may be questioned for the estimation of other parameters (productivity, longevity, survival rates, land tenure system, etc.).
It has been proved in other feline species that data referring to habitat use obtained with this system are similar to those obtained with radio--tracking [28]. Therefore we consider that estimation of use areas may be a valid approximation for their monitoring. During years these space units remain unchanged, as happens with females' territories [29]. Wild rabbit census have been carried out in detail since 2003. There have been wide rabbit fluctuations, and those variations have not affected the use areas. This might be based on supplementary feeding programs that were activated when rabbit populations were lower than the requirements estimated by Palomares et al. [15].
It might be evident that, in most cases the surfaces obtained for use areas are smaller than territories (see table 3), according to data obtained by radio-tracking [15,29]. Although this type of space unit has been suggested in previous work on European lynx, Lynx lynx [30], its stability along time had never been proved.
The results suggest that camera-trapping allows a precise characterization of status of at least part of the lynx population. Percentage of detection of reproductive animals in the thirteen use areas, globally considered, shows an average of 66.67%. The percentage rises to 77% if we consider only the use areas completely included within the study area. These data may increase in some cases reaching over 80% of territorial animals detected during some years. The maximum of located territorial lynx was 92 different locations. Thus we are able to locate with a high degree of precision their use area, considering the aims of the study.

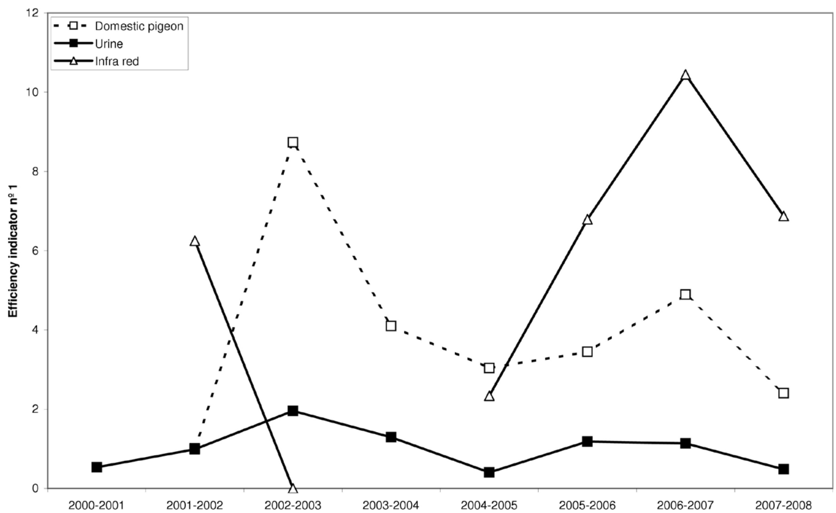

Fig. 3. Efficiency indicator nº 1 (relation between number of entries and 100 trap-nights) evolution.

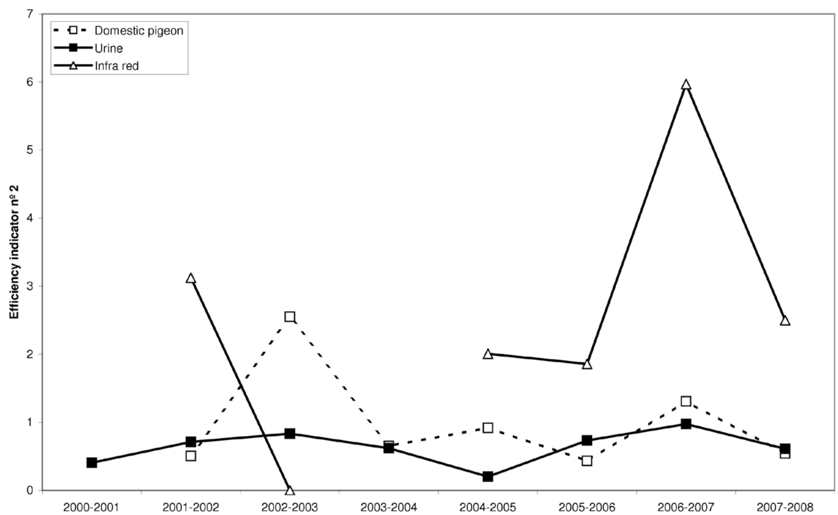

Fig. 4. Efficiency indicator nº 2 (relation between number of different lynxes and 100 trap-nights) evolution.

We will now try to compare data obtained with radio-tracking to those of camera-trapping. Using radio-tracking Palomares et al. [15] made an estimation of 0.77 ± 0.01 adult animals and 0.46 ± 0.07 non adult specimens for every $km^2$of territory. If use areas are used we obtain a total area (eliminating overlapping) of 1.624 hectares in 2007, counting a total of 9 adult territorial females, and 5-6 adult territorial males, representing an adult lynx density of 0.86-0.92 / km^2. The number of non territorial animals, during (2003-2007) is around 1.35-1.97 lynx / km^2. Both figures are higher than those obtained in Doñana N.P. This fact may be due to the clear methodological differences, to a population packaging effect or to a larger productivity in Andujar's sub-population compared to Doñana [31].

The mentioned results confirm that camera-trapping is a strong tool for the monitoring

of Iberian lynx population, providing enough information on the use of space, population structure and size, focused on preservation management. Of course it is limited if compared to other species [32], especially when considering the relationship between number of entries and effort done.
In order to improve efficacy of the different monitoring systems, the use of efficiency indicators should be generalized. In the present study an outstanding evolution in efficiency indicators has been shown. Camera-trapping with live prey is remarkable. After the first season (2002-2003) where a massive use of very high indicators took place with, they suffered a dramatic decrease during the next two seasons, especially indicator 1.This fact may be due to lynx learning ability, as they didnot obtain reward from incentives they stoppedanswering. Feline have a very high learning ability [16]. Differences between years can not be explained by different trapping methods used nor by station density in different years nor by the use of many common stations between seasons [32,33].

Use in the monitoring of stable populations

The above mentioned learning ability of felines forces constant innovation in order to obtain positive results with camera-trapping. The use of live prey as lure without reward may cause the loss of effectiveness of certain lure. The excellent results obtained with rabbit, basic Iberian lynx prey [34], during the first season, can decrease dramatically if used generally. So we propose its use only at the end of intensive campaigns, in short gaps and with only one station per use area. We propose to avoid the use of rabbit as lure during summer due to potential mortality caused by high temperatures, and the difficulties to maintain them appropriately.
On the other hand, olfactory stations can be regularly used considering their usefulness as a tool for census and for capturing the attention of territorial animals, but provide a low number of unique and total capture events.
Camera trapping with infra red equipments in active latrine seems to be the most profitable technique and the least influenced by behavioral changes, as it takes advantage of one of the species natural activities, marking and olfactory communication through faeces and urine in latrines. We propose placing at least one camera with urine as lure per use area during at least 30 days per year.
Anyway, new lures and techniques should be tested, because it is possible that lures initially successful show a dramatical decrease in the mentioned indicators.
It can be concluded that no technique should be discarded, but different systems should be combined according to information needed in each case:
Camera-trapping with live prey (pigeon and rabbit) is very effective for cubs and young animals, providing plentiful material, both of entries and animal pictures. It is the best method for reproduction monitoring and animal photo-identification.
Camera-trapping with scent stations is not profitable in terms of capture events , but it is profitable considering the number of different animals detected compared to effort done. This technique is especially recommended for monitoring adult lynxes, which are less prone to enter in stations with live prey. It also offers very valuable information about territorial use within the use areas borders.

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