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The effect of removing lynx in reducing attacks on sheep in the French Jura Mountains

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Abstract

The selective removal of carnivores from local areas is sometimes proposed to reduce the number of attacks on livestock. For the lynx, neither the existence of problem individuals nor the efficacy of their selective removal has been demonstrated. In France, from 1989 to 1999, eight lynx and two large carnivores thought to be lynx were legally removed from high conflict areas by trapping ($n=7$), shooting ($n=1$) or poisoning with toxic collars on sheep ($n=2$). The efficacy of the 10 removals was assessed on the farms where a lynx was caught and in the 5-km-radius areas encompassing both these farms and nearby sheep farms. The sex-ratio of captured lynx was seven males:one female. On four farms and in six 5-km-radius areas lynx attacks on sheep reappeared within 40 days after lynx removal, but we observed a significant decrease in the overall number of attacks. In the medium-term (48–365 days), the number of attacks decreased on two farms and in four 5-km radius areas when compared with the number observed in control plots >10 km away from the removal sites. In the long-term, attacks reappeared on the same sites, indicating a "site" effect. In such situations, selective removals may only temporarily reduce the problem of concentrated lynx damage. The only way to obtain a durable effect is to improve shepherding techniques.

Keywords: *Lynx lynx*; Lynx–livestock conflict; Problem individuals; Selective removal

1. Introduction

In Europe, population control of large predators has long been the favoured method to reduce depredation on livestock (Breitenmoser, 1998). The modern approach to resolve predator–livestock conflicts entails the selective removal of certain individuals in high conflict areas, rather than efforts to reduce overall numbers. Such selective removals consist of live captures, sometimes followed by the translocation of predators into other areas (Linnell et al., 1997), or lethal control. Theoretically, locally applied control does not jeopardize the existence of a population (e.g. MacCullough, 1996), and selective removals may contribute to the acceptance of carnivore presence if livestock are less often attacked. An argument in favour of this strategy is that "with regard to identified problem animals, which are causing local damage, emphasis should be given to maintaining populations and not by concentrating on individuals" (Boitani, 1998; Breitenmoser et al., 1998; Swenson and Dahle, 1998). The efficacy of these selective control methods, however, is based on the hypothesis that within a given population some individuals cause most of the problems and that these individuals can be eliminated. Until now, the existence of "problem individuals", i.e. individuals that kill more livestock per encounter than other ones, has only rarely been established (Linnell et al., 1999). The efficacy of the removal of certain individuals to avoid further damage has only been demonstrated in a few rare cases (e.g. Stander, 1990; review in Linnell et al., 1996). For the European lynx (*Lynx lynx*), no specific study has ever been carried out on this subject.

The French Jura massif has been colonized by the lynx since the middle of the 1970s (Herrenschmidt and Léger, 1987; Breitenmoser and Baetig, 1992). In this region, all large wild predators had disappeared for decades. Sheep were left unguarded in pastures frequently situated near or at the edge of the forest. The appearance of lynx attacks on sheep in 1984, and the

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sudden increase in the number of depredation events in 1988 and 1989, created violent conflicts with the sheep farmers (Grosjean, 1992). The cases of heavy predation, however, were localized (Vandel and Stahl, 1998a; Stahl et al., in press). In these areas with high depredation level, social pressure and the will to limit such damage persuaded the French government to authorise the removal of certain individuals under very restrictive conditions. These removals were carried out by state-employed agents, after official authorisation by the Ministry of the Environment. To ensure that removals only targeted sheep-predating lynx, attempts to capture or shoot lynx were made inside or within the immediate surroundings of the pastures where sheep had been attacked.

From 1989 to 1998, eight lynx were removed by trapping and shooting, and two large carnivores thought to be lynx were killed by toxic collars. This article attempts to evaluate the effect of these local removals on the number of lynx attacks on farms from which lynx had been removed, and in the hot spots, i.e. the larger area encompassing both the farm where the lynx was caught and the neighbouring sheep farms.

2. Study area

The French Jura massif covers about 10,000 km^2. Lynx are present on about 8000 km^2 (Vandel and Stahl, 1998a; Stahl and Vandel, 1999). The main area of sheep breeding is situated in the foothills of the mountain chain, at altitudes of 400–700 m (Fig. 1). In the Jura mountains, sheep are left unguarded in 1- to 100-ha pastures surrounded by electric fences or 1.2 m-high wire-net fences. These pastures lie scattered around farms and villages, and are often situated at the edge of the forest. Most of the flocks are of medium size, i.e. less than 100 ewes. In this region, lynx and dog are the only predators attacking flocks. No guard dogs are used in the Jura.

3. Methods

3.1. Census and identification of lynx attacks

Every attack (i.e. one or several sheep killed or wounded in a pasture in one night) declared by a sheep

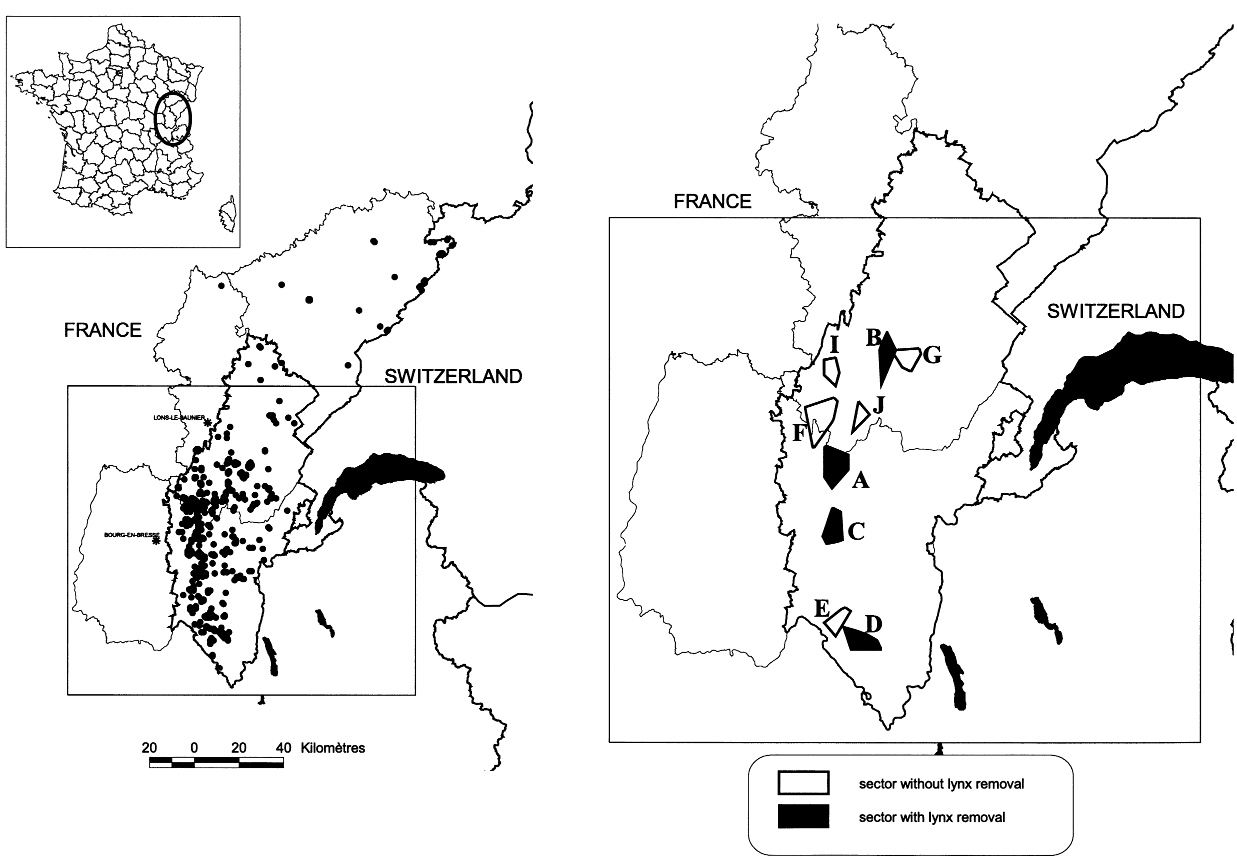

Fig. 1. Location of lynx attacks on domestic livestock in the Jura mountain massif (left) and location of the nine sites where hot spots were identified between 1984 and 1998 (right).

breeder was investigated by trained lynx experts, most of whom were state-employed agents (Vandel and Stahl, 1998b). Lynx experts attributed the cause of death to a predator if, after skinning, bite impacts associated with haematoma were found on the inner side of the skin. The main criteria lynx experts were looking for to discriminate between dog and lynx attacks were the presence of bite holes around the larynx, the diameter of bite holes (mostly < 3 mm in size), the presence of the typical 28–32 mm lynx canine spacing between pairs of isolated bite holes (see Roberts, 1986 for dog canine spacing) and the way the prey was eaten. Depending on the number and quality of these criteria observed on the carcasses or in the vicinity of the prey (tracks), attacks were classified as "confirmed", "probable", "doubtful", or "not attributed to lynx". In the following analysis only "certain" and "probable" lynx attacks were retained.

3.2. Lynx removal

Lynx were removed by live trapping ($n=7$), shooting ($n=1$) and by poisoning with 1080 (sodium monofluoroacetate) in livestock'protection collars' ($n=2$). Traps were set around the carcasses of sheep killed by lynx. In general, lynx are not scavengers and those captured when returning to a prey are the ones that killed this prey. Trapped lynx were held in captivity. Attempts to shoot lynx were made from a hide placed in pastures where many attacks had occurred in the preceding weeks. Livestock protection collars do not protect sheep from death but are an efficient and selective method of killing their predators (Savarie and Sterner, 1979; Connolly and Burns, 1990; review in Andelt, 1996). Sheep were equipped with these collars in two neighbouring pastures during summer and autumn 1990. Two of the equipped sheep were killed, one in each pasture. The wounds and bite marks were characteristic of lynx. Tooth punctures observed on the pierced collars were evidence that the predators had ingested the poison, although the carcasses of the poisoned animals were not found.

In 1989, 1990 and 1991, the authorizations to remove lynx concerned districts where in the previous summer sheep had been attacked. No threshold for the number of kills had been defined and removal attempts were made after varying numbers of lynx attacks (Section 4). In 1998, the lynx removal measure was aimed at a known male, identified by a radio-tracking study as the main sheep predator. This animal was removed when it attacked a flock at the limits of its usual home range.

3.3. Effect of lynx removals

The effect of lynx removals on the number of attacks was investigated at two spatial scales: (1) the sheep farm from which a lynx was removed and (2) the "hot spot" from which a lynx was removed. A hot spot was defined as a 5-km radius area encompassing the farm from which a lynx was removed as well as the nearby flocks. It was assumed that, within this limited area (7850 ha), all flocks could have been attacked by the same lynx. As no attempts were made to catch or kill lynx at the exact centre of a local damage area, hot spots were identified by a standard procedure based on the distribution of lynx attacks on sheep, regardless of the exact place of lynx removals. This procedure also allowed us to identify hot spot areas on sites without lynx removal and to compare the trend in the number of attacks in local areas with and without lynx removal. The following procedure was applied:

1. Each attack on a particular night was identified by its geographical coordinates X and Y, and the number of attacks over the year within a radius of 5 km was calculated.
2. The areas were ranked by the number of attacks until all hot spots with 10 or more attacks over the year had been identified.

Hot spots were redefined each year to take account of any possible change in the sheep locations or in the distribution of lynx attacks. Nevertheless, attention was paid to the fact that hot spots remained centered on farms with removal.

The short-term effect was evaluated by comparing the number of lynx attacks during the 40-day period before and after the night of lynx removal. During this period, all conditions that might have influenced the probability of an attack (number of sheep, environment, etc.) were assumed to have remained constant. Data were analyzed by Wilcoxon's matched pair rank test.

The medium-term effect of lynx removals was analyzed over a 365-day period before and after each removal, or over the time span between two removals when several lynx had successively been removed from the same site. For these longer periods, a direct comparison of the number of attacks recorded before and after the removals could be invalid because the number of sheep or their availability could have changed. To take these unchecked factors of variation into account, the pre- and post-removal number of lynx attacks was compared to the number of attacks recorded during the same periods on "control plots", i.e. in farms outside hot spot areas situated more than 10 km away from a site of removal. Comparisons were made by a Chi^2 or Fisher's exact test.

During 1984–1998, hot spots often reappeared roughly in the same places from year to year. When the annual hot spots that overlapped by $> 50\%$ of their surface area were grouped, we identified only nine distinct sites (range: 15.9–64.9 km^2) throughout the whole Jura mountain chain (Stahl et al., in press). Lynx were removed from four of these nine sites (Fig. 1). The very long-term effect (pluri-annual effect) of the lynx removals was then qualitatively examined by comparing the change in the number of attacks on these four sites with that on the five sites without legal removals. If less than 10 incidents occurred on a site during a particular year, i.e. no actual hot spot declared, then the actual number of attacks around the centre of the site (5 km radius) was used.

4. Results

4.1. Lynx removals

Seven of the eight removed lynx were males (five adults and two juveniles captured in winter) and one was a lactating female (Table 1). This sex ratio was significantly biased in favour of males (Chi^2 test of goodness-of-fit = 4.5; $P<0.05$).

4.2. Short-term effects

Lynx attacks on sheep reappeared within 40 days after lynx removal in four cases out of 10 on the farms, and in six cases out of 10 in the hot spots (Table 2). However, a significant decrease in the overall number of attacks was observed after the removals (Fig. 2) on the farms ($P<0.01$) as well as in the hot spots ($P<0.05$).

4.3. Medium-term effects

Because different lynx were captured at intervals <365 days, the study period varied between 48 and 288 days (Table 2). For the farms, only the fourth removal (adult male) on site B in 1991 ($P<0.05$; 288 days) and possibly the first removal (unknown predator) on site D ($P=0.06$; 114 days) had an effect compared to control farms. For the hot spots, and partly because of the slightly superior power of the tests, two other removals had a significant effect: the third removal (adult male) on site A ($P<0.001$; 365 days) and the removal (adult male) on site C ($P<0.01$; 365 days). Six removals had no effect : the removals of juvenile lynx in winter on sites A (210 days) and B (262 days); the removal of an adult female in summer on site A (210 days) and the successive removals of two adult males in autumn (48 days) on site B.

4.4. Pluri-annual trend

The annual changes in number of lynx attacks on the nine sites of the Jura where hot spots were identified between 1984 and 1998 are given in Table 3. Lynx were removed on sites A to D.

On site A, hot spots persisted for 4 years between 1990 and 1994 in spite of the removal of a sub-adult in December 1989 and of an adult female in the summer of 1990. Although no other lynx were legally removed on this site between 1991 and 1998, a low level of attacks was observed in 1995 and 1996. This level was concomitant with the settlement of a radio-collared female born in Switzerland on this site in the winter of 1994–1995. This female reproduced in 1995, did not attack sheep, and was illegally killed in autumn 1995. Serious attacks reappeared in 1997, mostly caused by a male that had been radio-tracked in this area since the summer of 1996. This animal was the one that had perpetrated most of the attacks in 1997. A decrease was recorded on this site in 1998, after its removal in March, 1998.

On site B, there was a 6-year period (1992–1997) without any hot spot after the fourth lynx had been removed in 1991. Resident lynx were radio-tracked on this site in 1996–1997. Then a hot spot reappeared in 1998.

Table 1
Legal removals of lynx in the Jura mountain massif (M, male; F, female; J, juvenile; A, adult)

Site	Animal	Date	Method of removal	Successive captures on the same site	
				Interval (days)	Distances (metres)
A	MJ1	31/12/1989	Trapping	–	–
	FA2	29/07/1990	Trapping	210	1840
	MA3	31/03/1998	Trapping	2802	2600
B	MJ5	02/01/1990	Trapping	–	–
	MA6	21/09/1990	Trapping	262	< 100
	MA7	08/11/1990	Trapping	48	< 100
	MA8	23/08/1991	Trapping	288	4420
C	MA4	26/04/1990	Shooting	–	–
D	X9	19/05/1990	Toxic collar	–	–
	X10	10/09/1990	Toxic collar	114	2520

On site C, no hot spot reappeared after a male was caught in 1991. Enquiries, however, revealed that the main sheep farms had disappeared in 1991.

On site D, a "history" of successive attacks and interludes was observed. A 3-year period without a hot spot was recorded after the second carnivore was killed in 1990. Hot spots appeared again in 1995, 1996 and 1998.

The history of sites E–I, without any lynx removals, was not fundamentally different from those with legal removals. On site E (close to D) no hot spots were observed after 1989, because of the disappearance of the main sheep farms in 1990. On sites F and G, hot spots appeared and disappeared in succession as on site D. On sites H and I, hot spots appeared in 1998 for flocks that had been present since 1988.

Table 2
Effect of lynx removals on the number of attacks on sheep farms and within hot spots from which lynx were removed[a]

Site	Animal	Study period (days)	Farm				Hot spot				Control farms	
			First attack after the removal (days)	Number of attacks			First attack after the removal (days)	Number of attacks			Number of attacks	
				Before removal	After removal			Before removal	After removal		Before removal	After removal
A	MJ1	210	6	14	4	NS	6	23	8	NS	21	18
	FA2	210	41	2	3	NS	9	9	5	NS	18	10
	MA3	365	> 600	0	0	–	84	26	3	***	17	24
B	MJ5	262	260	5	2	NS	145	10	6	NS	27	24
	MA6	48	41	2	2	NS	41	4	2	NS	7	2
	MA7	48	22	2	1	NS	3	2	2	NS	3	1
	MA8	288	1148[b]	7	0	*	252	17	1	**	16	20
C	MA4	365	89	7	1	NS	22	39	7	**	32	25
D	X9	114	9	11	8	NS[c]	9	12	9	NS[c]	5	16
	X10	114	27	9	3	NS	27	10	3	NS	15	6

[a] The study period is the number of days before and after the removal during which the effect was studied (=365 days or the maximum possible interval between the date of removal and another removal on the same site). The removal effect was assessed with respect to the number of lynx attacks recorded during the study period in control farms (= farms situated outside hot spot areas and at more than 10 km from the removal sites). NS, not significant.
[b] The pasture was then abandoned.
[c] $P=0.06$.
*$P<0.05$.
**$P\leqslant 0.01$.
***$P<0.001$.

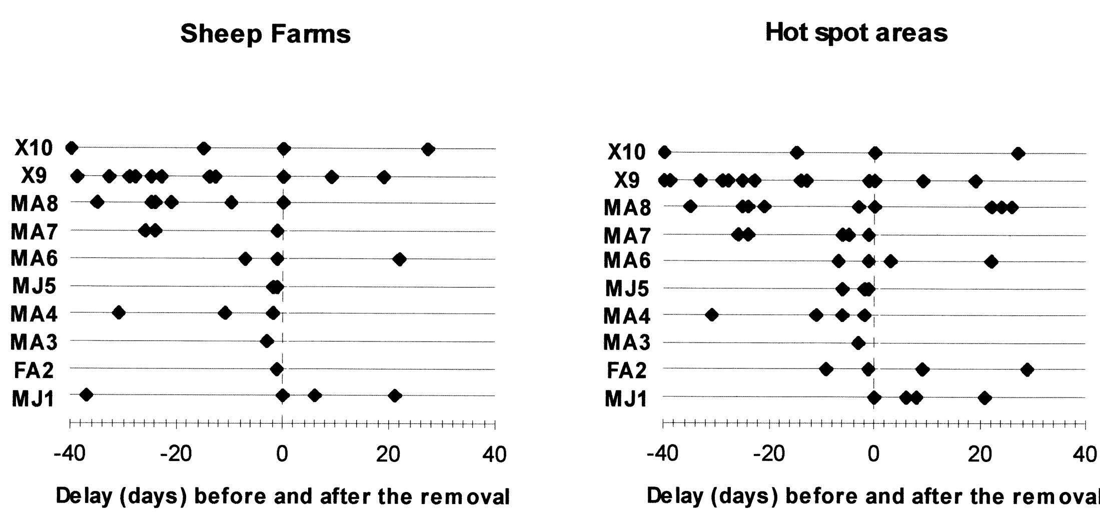

Fig. 2. Number of lynx attacks on sheep farms and in hot spots where lynx had been removed, during the 40 days before and after lynx removals. Lynx identification numbers: refer to Table 1.

Table 3
Changes in the number of lynx attacks on the nine sites of the Jura mountain massif where hot spots with at least 10 attacks had been recorded between 1984 and 1998 (sites with legal lynx removals: A–D; sites without legal lynx removals: E–I)

Site	Area (km^2)	Number of attacks (animals removed)											Total
		1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	
A	54.7	6	26 (MJ1)	13 (FA2)	10	11	19	12	3	3	33	6 (MA3)	142
B	34.8	1	11	10 (MJ5; MA6; MA7)	15 (MA8)	3	4	6	6	5	6	16	83
C	38.3	10	31	16 (MA4)	4	3	4	2	4	1	0	3	78
D	38.0	43	45	24 (X9; X10)	1	5	4	14	31	6	9	10	192
E	24.6	5	13	6	0	0	0	2	0	0	2	**0**	28
F	64.9	2	7	6	3	5	1	14	12	22	2	31	105
G	30.1	1	2	10	14	23	19	13	10	6	13	11	122
H	15.9	2	7	1	0	4	3	2	3	2	9	11	44
I	22.2	0	0	3	0	0	0	0	0	1	0	11	15
Total	323.3	70	142	89	47	54	54	65	69	46	74	99	809

5. Discussion

5.1. *Effect of lynx removals*

As with other large carnivores, lynx predation on livestock may be important only locally. In a review of the data available for 11 European countries, Kaczensky (1996) estimated that lynx annually kill 0.01%–0.55% of the available stock. The predation rate on sheep in the Jura mountains is also low: some 100–400 sheep are killed by lynx each year out of a total number of sheep estimated at 36,000 (Ministère de l'agriculture, 1988a, b, c). Nevertheless between 1974 and 1998, >70% of the attacks were concentrated on only nine small sites which covered 1.5% of the area with attacks (Stahl et al., unpublished). This high concentration of damage on a few sites indicated that attacks were due to a small number of lynx.

In the lynx, male and female home ranges as well as resident and transient sub-adult home ranges overlap (Breitenmoser et al., 1993; Schmidt et al., 1997; Zimmermann, 1998). This spatial organization implies that several individuals may frequent the same sheep pastures. It is, therefore, not surprising that attacks did not always stop completely after the removal of a lynx. The fact that not all lynx removals were followed by a significant drop in the number of attacks — but not by a complete stop — deserves more attention. Theoretically, lynx removal in high-damage areas will have a short- or medium-term impact if (1) the majority of the attacks recorded in a hot spot are due to one individual and if (2) this individual is the one removed. The presence of cattle-predating individuals has been recorded in bear (e.g. Camarra et al., 1993; Anderson et al., 1997) and in a few large cat species (Rabinowitz, 1986; Stander, 1990; Hoogesteijn et al., 1993; Mizutani, 1993). In this study, three instances provided evidence that a lynx had focused on sheep and that it was eliminated by selective methods. In these cases, a high number of lynx attacks was observed over a short period of time in a restricted area and the removal was followed by a sudden decrease in the number of attacks. The other removals were not so effective despite the use of the same selective methods. In some cases, lynx were removed after only a few attacks had been registered over a period of several weeks. In other cases, the time interval between repeated removals from the same site was short. Lynx attacks on sheep in these circumstances did not necessarily correspond to attacks committed by an individual focusing on sheep. These removals, as well as their timing, were probably carried out to satisfy a strong social demand in a situation of serious conflict, or in an utopian attempt to stop all attacks on sheep. Finally, the removal of two juveniles at the end of the year was also a rather ineffective measure. These young males were caught in late winter by live-trapping around a sheep carcass. Because of their small size, they were not the ones that had caused the numerous attacks recorded during the previous summer and early autumn. As juveniles are frequently the first to approach the prey, they were more probably just caught near a prey killed by their mother.

In the longer term, the removal of a solitary, territorial large cat always creates a void that may be filled by nearby individuals expanding their home ranges (Anderson, 1988) or by the installation of transients (Knick, 1990; Lindzey et al., 1992; Laing and Lindzey, 1993). In the Jura, the reappearance within a few years of lynx regularly attacking sheep on the same sites clearly indicates a "site effect", i.e. an interaction with the specific characteristics of the site (e.g. location of sheep pens in forested areas, availability of wild prey, etc.). Under these conditions, removals can only solve the problem of lynx attacks in the short-term.

5.2. Lynx implicated in livestock predation

In felids, some observations suggest that important depredations are mostly due to males (Jaguar: Rabinowitz, 1986; Lion: Stander, 1990; Saberwal et al., 1994; Leopard: Mizutani, 1993) and sometimes to old or wounded animals (Rabinowitz, 1986; Fox and Chundawat, 1988; Hoogesteijn et al., 1993). The preponderance of males could be due to the more extensive movements of this sex, which lead to more frequent contacts with cattle (Linnell et al., 1999). In our study, none of the removed animals showed any physical abnormality which would have prevented them from capturing wild prey. Furthermore, the hypothesis of an essentially male predatory behaviour on sheep cannot be substantiated if one takes into account the fact that two of the males were juveniles and were not at the origin of a hot spot.

5.3. Management implications

To avoid removal attempts when only occasional sheep predators are present, a threshold must be defined for the number of kills. This threshold should be established for a given season, and for an area smaller than that of a lynx home range. In the Jura mountain massif, a threshold of at least 10 incidents (i.e. 15–16 killed sheep) within a 5-km radius seems justified because below this level, no adult lynx removal has had any effect. In any case, hot spots should be identified quickly. A systematic recording procedure for lynx attacks is a useful tool. To reduce the risks of capturing only occasional sheep predators, the delay between the appearance of the hot spot and the removal of the predator should be short, and the operation should be carried out near the centre of the hot spot. In highly endangered lynx populations, lynx should be trapped and radio-tracked before removal to ensure that only the targeted lynx is removed. One cannot totally exclude the possibility that removal of a juvenile that has "learned" to consume sheep will have a long-term effect, but there is little evidence of such a local tradition of depredatory behaviour within large felid families (e.g. Stander, 1990; Nowell and Jackson, 1996 for a general review). Until new evidence is obtained, captured juvenile lynx should be released. If a "site" effect exists — validated by long-term monitoring of the damages or specific in-depth studies — the direct implementation of measures to protect flocks, for example with guard dogs, is the only way to obtain a lasting effect.

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