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ORIGINAL PAPER

Comparison of the effectivity of different snare types for collecting and retaining hair from Eurasian Lynx (*Lynx lynx*)

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Abstract Genetic methods are increasingly being used as noninvasive tools to survey populations of wild animals. One challenge of these methods is the sampling of genetic material from the target species. Genetic material of various predators, such as bears, canids, and felids, has been successfully obtained from both hair trapped in snares and scat. However, there is currently no standard procedure for sampling genetic material from the Eurasian Lynx (*Lynx lynx*). We tested established and newly developed hair snares in two near-natural lynx enclosures in the Bavarian Forest National Park. All snares consisted of a wooden post; they differed in the type of material attached to the post for snaring hair: carpet (velour with 40 nails), wildcat (spruce wood with 2–3 mm deep, horizontal and diagonal ridges), wire brush, doormat, or rubber bands (250 g of rubber bands wrapped around the post). We determined the acceptance of the hair snares by the animals by observing their behavior with the aid of video cameras. The number of rubbing events on the different trap types did not significantly differ, but the rubbing duration was longer for the doormat hair snare. The wire brush hair snare collected the highest total amount of hair and — beside the carpet — the highest amount of hair per unit of time. Almost all hair trapped on the wire brush snare were retained during a 2-week exposure to the elements outside of the enclosures. The results of our study may hold for other felid species with hair characteristics similar to those of lynx.

Keywords Hair trapping · European Lynx · *Lynx lynx* · Noninvasive sampling · Monitoring · Genetic monitoring

Introduction

The protection and management of species should be always based on a well-founded management program. An essential component of such a program is the availability of extensive information on the habits and ecology of the species and on their numbers and population trends (e.g., Linnell et al. 2008).

Such information is often difficult to collect, especially on elusive felids. Felids, except lions and domestic cats, lead a solitary life, with only females spending time with their offspring. Felids are rarely observed because they often require large territories, occur at low densities, are nocturnal, are well camouflaged, and often live in habitats with dense vegetation cover (Sunquist and Sunquist 2002). All these characteristics make the estimation of the current and future densities of felids one of the most difficult tasks in wildlife biology (Linnell et al. 1989). Traditional monitoring methods for felids are systematic snow tracking (Jedrzejewski et al. 1996; Hayward et al. 2002; Linnell et al. 2007a, b), use of scent stations (Sargeant et al. 2003), and analysis of hunting

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bags. Methods introduced recently include the use of detection dogs (Harrison 2006; Long et al. 2007) and automatic cameras (Cutler and Swann 1999; Laass 2001; O'Connell et al. 2011).

Another modern survey method is genetic monitoring. Such DNA-based methods can provide information about abundance and detailed population structure, such as the sex ratio, individual identity, the relatedness of individuals, and population-level metrics, including variability, isolation, and dispersal rate (Woods et al. 1999; Proctor et al. 2005; Ritland 1996; Luikart and Cornuet 1998; Schwartz et al. 2007). DNA has been extracted from collected scat samples and animal hair. Hair has the advantage that its DNA is less degraded than DNA extracted from scat (Kendall and McKelvey 2008), thereby yielding more consistent results at a far lower cost of material and analysis (Long et al. 2007; Bonaker 2008). In investigations over large areas, animal hair has been collected using scented devices upon which animals deposit hair (Harrison 2006). In recent years, these hair snares have been successfully used to collect genetic samples from various carnivores, such as black bears (*Ursus americanus*) (Gardner et al. 2010), ocelots (*Leopardus pardalis*) (Weaver et al. 2005), bobcats (*Lynx rufus*) (Ruell and Crooks 2007), fishers (*Martes pennati*), American martens (*Martes americana*) (Williams et al. 2009), San Joaquin kit foxes (*Vulpes macrotis mutica*), and swift foxes (*Vulpes velox*) (Bremner-Harrison et al. 2006).

For hair collection to be effective, a method has to be designed for each given target species or group of species, considering body size, hair characteristics, and animal behavior. Therefore, a number of different hair collection methods have been developed. These include hair corrals, rub stations, tree and post hair snares, and cubbies (see overview in Kendall and McKelvey 2008). For lynx, the first hair snares were designed by Weaver et al. (1997), who had observed a tame Canada Lynx (*Lynx canadensis* Kerr 1792) rubbing against a post, leaving some hair behind (Turback 1998). This behavior has been exploited to acquire hair to determine the presence of lynx in a given habitat and for genetic studies. Lynx find the hair snares set along their trails with the aid of visual and olfactory attractants Belant 2003; Schmidt and Kowalczyk (2006). Effective attractants that trigger the rubbing behavior include beaver castoreum, catnip oil, and lynx urine (McDaniel et al. 2000; Mestemacher et al. 2007). The hair snares recommended by Weaver et al. (1997) were made from a piece of carpet pierced with numerous nails. In a slightly modified form, these snares were used in investigations by McDaniel et al. (2000), Downey et al. (2007), Harrison (2006), and McKelvey et al. (2006).

The goal of our study was to develop more efficient hair snares and to compare their effectiveness and practicability with the snares currently used for the Canada Lynx (*Lynx canadensis*; Weaver et al. 1997) and the Eurasian Wildcat (*Felis silvestris*; Weber et al. 2008; Hupe and Simon 2007). We compared the rubbing frequency and duration, acquisition of hair (number of hairs attached), and retention (number of hairs remaining after 2 weeks) of five different types of hair snares made of rough-sawn spruce (unplaned).

Material and methods

Design of the hair snares

All hair snares (Fig. 1) consisted of a 130×6×6 cm squared wooden post, pointed on one end and made of rough-sawn spruce. Eight snares of each type were made. To rule out any influence of snares used in previous experiments, a new snare was used for each experiment.

The "carpet hair snare" was based on the modification of Schmidt and Kowalczyk (2006) of the high-pile (8 mm) velour carpet hair snare described by McDaniel et al. (2000). The size of the carpet used by these authors (8×8 cm) was increased to 10×30 cm to obtain a rubbing surface size comparable to that of the "doormat hair snare" (see below). Forty galvanized roofing nails were pushed through the back of the carpet, and the tips were cut off with pliers 2 cm above the carpet surface. The same type of nail was used to fasten the carpet to the posts.

The "wildcat hair snare" was a modification of the snare described by Hupe and Simon (2007) and consisted only of the wooden post, but with 2- to 3-mm-deep, horizontal and diagonal ridges made using a fine-toothed saw. The posts were then scraped with a chisel and roughened with a wire brush.

For the "rubber band hair snare", 250 g of household rubber bands (65 mm in diameter, 1 mm thick) were wrapped around each post, distributed between heights of 80 and 120 cm.

The "doormat hair snare" consisted of a textile doormat (40×30 cm) wrapped around the post between heights of 80 and 120 cm. A knobbed rubber mat (13×13 cm) was placed above, and a piece of sandpaper (grain size 0.3) for a delta sander was attached to one of the four sides of the post on the doormat. The doormat/rubber mat unit was fastened to the post with galvanized roofing nails.

The "wire brush hair snare" consisted of a new wire brush with four rows of brass wire, with the brush head surrounded by a 30-cm-wide piece of high-pile (8 mm)

Fig. 1 The tested hair snares (*left* to *right*): carpet, rubber band, wire brush, doormat, and wildcat

velour carpet, in which a hole large enough for the brush head was cut. The brush/carpet unit was wrapped around the post with the brush handle facing upward and the brush wires exposed. The brush wires were bent by rolling and striking them with a piece of iron pipe.

Each post cost €1. The wildcat hair snare incurred no additional material costs. The other snares incurred additional material costs of €2 for rubber bands, €2 for carpet, €2.50 for the wire brush, and €4 for the doormat. The cost of the posts of the carpet, wire brush, and doormat hair snares could be alleviated by fastening the snares to trees (Schmidt and Kowalczyk 2006). The rubber band hair snare was the simplest and quickest (4 min) to assemble, followed by the wildcat hair snare (5 min), the doormat hair snare (7 min), and the carpet and wire brush hair snares (8 min).

Olfactory attractant

A combination of beaver castoreum (powder gained by dried beaver sacs) and catnip oil as an olfactory attractant has been successfully used by McDaniel et al. (2000), Schmidt and Kowalczyk (2006), and Mestemacher et al. (2007) to collect lynx hair. We mixed powdered beaver castoreum with ethanol (1:10 wt/vol) and then, following Schmidt and Kowalczyk (2006), added catnip extract (catnip extract/castoreum solution, 1:32 vol/vol). One volume each of propylene glycol and glycerine were added to 6 volumes of the mixture to reduce evaporation and prevent freezing. At the beginning of each test series, 5 ml attractant solution was applied to each snare type.

Enclosures and test animals

We tested the hair snares in lynx enclosures in Neuschönau and Ludwigsthal in the Bavarian Forest National Park. Both enclosures are designed to emulate natural conditions and represent the natural montane mixed forest environment of the lynx. The lynx enclosure TFG I in the wild animal park in Neuschönau is approximately 8,900 m^2 and contains a 15-year-old female and an approximately 13-year-old male. The lynx enclosure TFG II in the wild animal park in Ludwigsthal encompasses an area of 3,600 m^2 and is occupied by a 9-year-old male and a 3-year-old female.

Enclosure tests

We tested the hair snares over a 4-week period between the end of November and mid-December 2009. Each week, one test of all snare types was carried out in each enclosure for 3 days. The 4 days in between the tests served to reduce the possibility of the earlier tests influencing the later tests. The posts with freshly applied olfactory attractant were installed 1 m apart during the animals' feeding time and in the presence of caretakers. For each test sequence, the hair snares were set up in a different order to preclude a potential bias caused by position.

Video cameras remotely controlled by motion sensors were installed to monitor the number of visits to and duration of rubbing against the various models. Infrared spotlights were coupled to the cameras to record night-time activity. The cameras were on 24-h standby and were provided with sensors for immediate activation. The total surveillance time in TFG II was 288 h. Because of a camera malfunction during one test in TFG I, the total surveillance time was reduced to 216 h. Because of the physical similarity of the lynx individuals and the quality of the video recordings, it was not possible to distinguish between individuals.

Although no nuclear DNA is present in hair shafts, shafts without roots can provide useful DNA from dander, saliva, or DNA-containing tissue that adheres to hair as it grows (Williams et al. 2003). Therefore, all hairs in the snares were considered. The total number of hairs was determined as follows. The collected hair was placed in a Petri dish and weighed (Sartorius laboratory scale 1213MP; measuring accuracy: 0.01 g). If the weight of a hair sample was <0.01 g, the hairs in the sample were counted; if the number exceeded 200, the number was rounded to the nearest 10. If the weight of a sample was >0.01 g, the number of hairs in 0.01 g was counted, and the total number of hairs was estimated by multiplying this figure by the weight of the sample.

Since hair roots contain DNA and are, therefore, of greater significance than hair shafts for genetic analysis, we determined the proportion of hairs with roots by examining 100 hairs of each sample under a stereomicroscope. For samples with <100 hairs, all hairs were examined.

Results were analyzed with R (R Development Core Team 2010). The count data consisted of the number of rubbing events, rubbing duration, number of hairs and number of hairs per time interval per 3 days. Therefore, to test the influence of hair trap type, we fitted generalized linear Poisson mixed models with multivariate normal random effects based on penalized likelihood (function glmm.PGQL of package MASS; Venables and Ripley 2002) with enclosure and observation as random factors to account for replicated measurements on each enclosure and with an observation-specific random intercept to account for possible overdispersion (Elston et al. 2001). To identify significant differences between pairs of habitats, we computed Tukey's all-pair comparisons and associated confidence intervals corrected for multiple comparisons (function glht of package multcomp; Hothorn et al. 2008).

Snare hair retention

We tested the ability of the different types of hair snares to retain hair by setting up the snares with trapped hair from the first and second weeks of the enclosure tests again, but this time outside enclosures. The locations were chosen such that the hair snares would be exposed to wind, sunlight, snow, and rain. We determined the loss of hairs after 2 weeks of exposure. Since it is not possible to count the hairs on the posts without removing the hairs, our method was not suitable for counting the hairs at the beginning, after 1 week, and after 2 weeks. Therefore, we estimated the numbers of hairs by eye, and classified the results in the following six categories based on the results from the first set of enclosure tests of hair snares, in which highly variable amounts of hair were collected: none (0), very few (1–40 hairs), few (40–100 hairs), moderate (100–200 hairs), many (200–300 hairs), and abundant (>300 hairs). These categories are intended to reflect the interdependency between the number of hairs lost and the total amount collected. The significance of such a loss increases with the decreasing number hairs that were caught and retained. The hair snares were photographed after each phase of the test. The photographs served as a calibration for the estimates so that the amount of hair could be assigned to the individual categories as precisely as possible. At the end of the experiment, the hairs were collected, and the exact number was counted.

Results

During the enclosure experiments of the different types of hair snares, we observed a total of 148 rubbing events with a combined duration of 64 min. A total of 15,864 hairs were collected in total (Tables 1 and 2, Fig. 2). All hair snare types were used at least once. The video recordings showed that the lynx always smelled the hair snares soon after they were set up in the enclosures, and usually rubbed against only one post before leaving the site. Only once did a lynx systematically rub each of the hair snares, one after the other, from right to left.

The doormat (*n*=40) and rubber band (*n*=37) hair snares were used the most, followed by the wire brush (*n*=27), wildcat (*n*=23), and carpet hair (*n*=21) snares. However, the differences between the models were not significant (Table 2). The absolute rubbing time for the doormat (1,439 s) and rubber band (1,310 s) hair snares was also longer than for other snare types, followed by the wire brush (605 s). The shortest duration of rubbing was observed in the carpet hair snares (213 s) and by the wildcat (298 s) hair snare. The mean rubbing time against doormat (36.0 s) was significantly higher than the mean rubbing time against carpet (10.1 s) and wildcat snares (13.0 s; Tables 1 and 2).

Most hairs were collected by the wire brush (7,514) hair snare, followed by the carpet (3,129), doormat (2,916), and rubber band (1,823) hair snares. The fewest hairs were collected by the wild cat hair (419) snare. The differences between wire brush and wild cat as well as doormat and wild cat were significant (Tables 2 and 3). Concerning the hairs with roots also the wire brush (2,947) hair snare collected the most hairs, followed by doormat (1,086) and carpet (969). The fewest hairs with roots were collected by the hair snares rubber band (487) and wild cat (136). The differences between wild cat and all other hair snares were significant (Tables 2 and 3).The amount of hair collected per unit of time of rubbing on the hair snares carpet and the wire brush was significantly higher than that obtained with the other models (Table 2).

The hairs on the carpet and wire brush hair snares could be much more easily identified when the color of the carpet strongly contrasted with the hair. Collection of hair from these models was facilitated by the agglomeration of hairs in the vicinity of the nails and the wire brush. The lack of contrast between the light color of lynx hair and the yellowish spruce post made it difficult to find hairs on the wildcat hair snare. The rubber element of the doormat hair snare collected mostly finer hairs, which contrasted starkly with the material. However, it was difficult to find hairs on the doormat used in these tests because of the white threads woven through the brown material. Hairs that were entangled between the rubber bands of the rubber band hair snare were highly visible and could be collected easily by removing the rubber bands.

We determined the hair retention of the different types of snares by estimating the hair loss from snares from the enclosure experiments that were set up outside of the enclosures and exposed to the elements for 2 weeks. Most hair loss occurred within 1 week (Table 4). Hair on the carpet

Table 1 Total duration and number of rubbing events for each type of hair snare and animal enclosure (TFG 1 and TFG II)

Hair snare	TFG I		TFG II		Total		Mean ± SD
	Duration (s)	*n*	Duration (s)	*n*	Duration (s)	*n*	
Carpet	182	16	31	5	213	21	10.1±7.6
Wildcat	261	18	37	5	298	23	13±16
Rubber band	1,204	28	106	9	1,310	37	33.5±34.4
Doormat	576	22	863	18	1,439	40	34.8±47.3
Wire brush	503	21	102	6	605	27	22.4±104
Total	2,726	105	1,139	43	3,865	148	26.1±41.3

Mean value and standard deviation are calculated from 148 observed rubbing events

Table 2 Differences in rubbing duration, number of hairs with roots, and number of hairs left per second of rubbing, expressed as the *p* values of Tukey contrasts after generalized linear Poisson mixed models with multivariate normal random effects based on penalized likelihood with enclosure and observation as random factors to account for replicated measurements on each enclosure and with an observation-specific random intercept to account for possible overdispersion

Hair snares compared		Rubbing frequency		Rubbing duration		Hairs total		Hairs with roots		Hairs per second	
		z	*p*	*z*	*p*	*z*	*p*	*z*	*p*	*z*	*p*
Carpet	Wildcat	0.269	0.999	0.300	0.998	−2.226	0.169	−3.422	0.006	−3.670	0.002
Carpet	Rubber band	1.677	0.446	2.186	0.182	−0.538	0.983	−0.919	0.890	−3.144	0.014
Carpet	Doormat	2.294	0.145	3.216	0.011	0.498	0.987	0.714	0.953	−4.050	<0.001
Carpet	Wire brush	0.528	0.984	1.385	0.634	1.154	0.776	1.264	0.713	−0.244	0.999
Wildcat	Rubber band	1.419	0.613	1.940	0.293	1.735	0.410	2.502	0.09	0.574	0.979

hair snare was either only loosely attached to the surface of the carpet or was more tightly held around the nails. Hairs collected by the doormat hair snare were often embedded deeply in the material of the mat or in the slits between the ridges of the mat because of the extensive rubbing behavior of the lynx, and were therefore well retained. The rubber mat component of this model retained very thin hair, but the sandpaper did not retain much hair. The rubber band hair snare poorly retained hair. Hairs attached to the wire brush hair snare were almost exclusively found in the vicinity of the wire brush, were tightly intertwined with each other and the wires, and were therefore well retained. The adjacent pieces of carpet retained only few hairs. The hairs that fell off of all the hair snares were originally only attached loosely to the material. Such losses were observed with each of the types of hair snares, but to different extents. After the first week, the number of hairs for three wildcat hair snares, three carpet hair snares, two doormat hair snares, and one

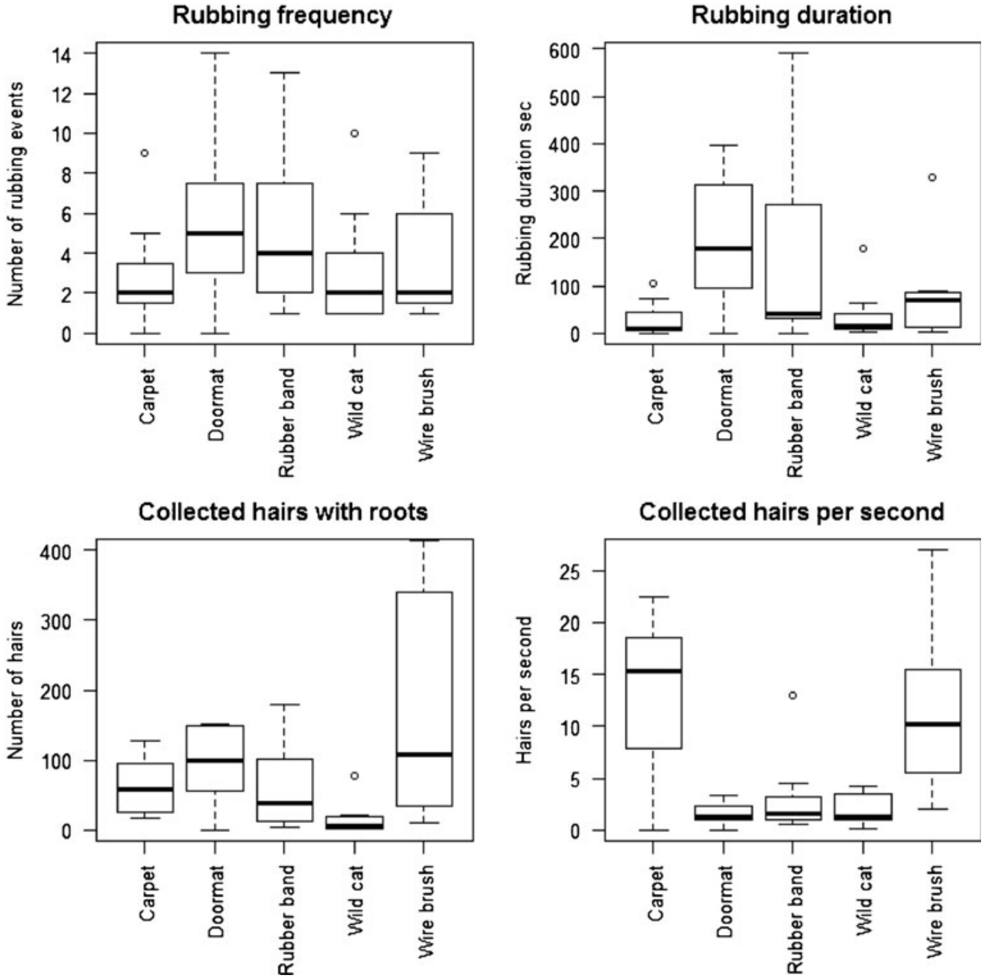

Fig. 2 Boxplots of rubbing frequency ($n=7$), rubbing duration ($n=7$), collection of hairs with roots ($n=8$) and collected hairs per second ($n=8$). The *boxes* show the median, the upper quantile and the lower quantile. *Whiskers* the 1.5 * interquartiles distance, *small circles* extreme values

Table 3 Number of collected hairs and collected hairs with roots (brackets) from each type of hair snare and animal enclosure ($n=8$)

	Test 1		Test 2		Test 3		Test 4		Total	Mean ± SD
	TFG I	TFG II	TFG I	TFG II	TFG I	TFG II	TFG I	TFG II		
Carpet	410 (127)	170 (65)	130 (56)	62 (31)	2,100 (609)	230 (62)	90 (19)	0 (0)	3,192 (969)	399±653 (121±201)
Wildcat	62 (16)	2 (2)	23 (6)	5 (2)	52 (8)	68 (22)	200 (78)	7 (2)	419 (136)	52±61 (17±24)
Rubber band	940 (179)	32 (9)	270 (97)	53 (17)	122 (39)	13 (4)	280 (104)	113 (38)	1,823 (487)	228±285 (61±57)
Doormat	0 (0)	380 (148)	280 (123)	240 (77)	1,350 (473)	186 (54)	150 (59)	330 (152)	2,916 (1,086)	365±388 (136±136)
Wire brush	360 (88)	41 (13)	210 (55)	620 (267)	175 (65)	28 (11)	4,960 (2,034)	1,120 (414)	7,514 (2,947)	939±1,557 (368±643)
Total	1,772 (410)	625 (237)	913 (337)	980 (394)	3,799 (1,194)	525 (153)	5,680 (2,294)	1,570 (606)	15,864 (5,625)	1,983±1,707 (703±672)

Table 4 Loss of hairs from the different types of hair snares after 2 weeks

	Mean category		
	At beginning	After 1 week	After 2 weeks
Carpet	5.25	4.50	4.50
Wildcat	3.50	2.50	2.00
Rubber bands	4.50	4.25	4.25
Doormat	4.75	4.25	4.25
Wire brush	4.75	4.75	4.75

The snares from the first and second weeks ($n=20$) of the enclosure tests were set up outside of the enclosures to observe the hair loss over time. Each value represents a change to a lower category. Categories: *1* none (no hairs), *2* very few (1–40 hairs), *3* few (40–100 hairs), *4* moderate (100–200 hairs), *5* many (200–300 hairs), *6* abundant (>300 hairs)

rubber band hair snare were assigned one category lower. Only the wire brush hair snares stayed in the same category. Fewer hairs were lost by all types of hair snares during the second week. Only the wildcat hair snares were assigned a category lower. It was observed that new snow had a positive effect on the duration of hair retention by the snares if they remained covered with snow and the snow did not melt.

Finally we performed an overall evaluation (Table 5). Hereby the hair snare wire brush obtained the best results. It collected more hairs with roots and was able to gather the hairs even when the rubbing event was very short. Also, the hair retention and the practicability in the field were good. The worst result was obtained by the hair snare wild cat. This hair snare performed especially bad in rubbing duration, collection of hairs with roots and retention of hairs. The results for the other models are shown in Table 5.

Discussion

The hair snares used in our study exploit the natural cheek-rubbing behavior of many small felid species (Weaver et al.

Table 5 Overall evaluation of the different types of hair snares

Criteria	Carpet	Wildcat	Rubber bands	Doormat	Wire brush
Rubbing frequency	0	0	0	0	0
Rubbing duration	−1	−1	1	1	0
Number of hairs with roots	0	−1	0	0	1
Hairs per second	1	0	0	0	1
Hair retention	−1	−1	1	0	1
Practicability	1	0	0	−1	1
Total score	0	−2	2	1	4

Scores: *1* good, *0* average, −*1* poor

2005) as well as the curiosity that cats display towards new objects in their environments (Luedicke 2004; Ehlert 2005). As expected, the lynx showed interest in all of the hair snares placed in their enclosures. During our study, it was not possible to determine significant differences in the animals' choice of the various models, but the lynx tended to rub longer on models without sharp nails and edges, but with some structure (cf. Fig. 2). Accordingly, they rubbed against the doormat and rubber band hair snares for longer periods than against the wire brush, carpet, and wildcat hair snares.

The materials used in these hair snares collected hair to different extents. In both enclosures, the wildcat hair snare collected the smallest amount of hair, and the wire brush hair snare collected the largest amount. This was followed by the carpet hair snares in enclosure TFG I and the doormat hair snare in enclosure TFG II.

The amount of attached hair was often far in excess of the amount required for genetic evaluation a large number of hairs reduce the risk that the amount of DNA might not suffice for analysis (Mestemacher et al. 2007) and a larger amount of hair is easier to detect on the snares. According to Mills et al. (2000), the minimum number of felid hairs required for DNA analysis is one. However, the optimum number is actually based on the number of hairs required to produce the lowest error rates in the analysis. Because felid hair is characteristically very thin, a single hair only rarely contains sufficient DNA to identify individuals reliably (Kendall and McKelvey 2008). McKelvey et al. (2006) specify a requirement for 1–10 hair roots, Mills et al. (2000) recommend 5–10, and Goossens et al. (1998) showed that with ten hairs, the error rates fell considerably in comparison to analyses with one or three hairs. For this reason, we especially noted samples with less than ten hair roots. One wire brush hair snare captured only 11 hairs with roots, but the remainder captured more. One carpet one doormat hair snare, two rubber band hair snares, and five wildcat hair snares captured less than ten hairs with roots.

Various factors, such as moisture, rust, castoreum particles, entanglement, and ensnaring promote the attachment of hairs. None of these factors are relevant for the wildcat hair snare, and accordingly, this model did not capture many hairs and suffered the greatest loss of hairs. Hairs attach to carpet, as found on the carpet, wire brush, and doormat hair snares, also because of electrostatic forces (Mestemacher et al. 2007). The wire brush hair snare trapped even more hairs than the other snares with carpet because of the dense metal wires of the wire brush. The entwining of the hair with the wires was so strong that almost no hair was lost after 2 weeks of exposure to the elements. Similar results have been obtained with hair corrals built of barbed wire (Boulanger et al. 2008), but barbed wire is most useful for collecting hair long enough to get pinched between the twisted wires of the barbs, e.g., hair from bears, canids and wolverines (Kendall and McKelvey 2008), and not for the shorter lynx hairs. For this reason and because of animal welfare concerns, we chose not to test barbed wire. Likewise, we chose not to test glues because lynx preferably rub the sides of their heads against the hair snares, and even the use of solvent-free glues would risk the danger of glue sticking to sensitive areas, such as around the eyes. Also, lynx typically avoid hair snares containing glues (Tree Tanglefoot®; McDaniel et al. 2000). Moreover, glues contain solvents that might interfere with DNA analysis, they are messy to work with, and more time would be required to remove the hairs from glue snares than from wire snares.

We carried out the study during winter because this is probably the best season to collect lynx hairs. First, the rutting period occurs in winter, and therefore marking behavior is increased. Second, winter fur is longer than summer fur. Third, female lynx move little after giving birth in the end of May, which reduces the probability of obtaining samples. Fourth, lynx walk the longest distances during winter, especially during the mating season, thereby increasing the chances of obtaining samples. For these same reasons, other survey methods, such as snow tracking and camera trapping, are performed in winter as well. A combination of survey methods in winter would provide different types of information that could supplement each other and require limited additional effort and expense.

It was not possible to precisely quantify the effects weather on the loss of hairs from the snares. The attached hair amounts were estimated by eye once per week, and the weather conditions changed daily. However, with temperatures around the freezing point, the temperature-dependent thawing and freezing of freshly fallen snow, and the high variation in the number of sunlight hours, the conditions were typical for winter in central Europe.

The hair snares placed outside of the enclosures were controlled for hair retention twice in a period of 2 weeks. A shorter period was not selected because the application of hair snares in large-scale surveys makes it impractical to check the snares more frequently than every 7 days. Schmidt and Kowalczyk (2006) also recommend a longer interval of 10–14 days, which takes into consideration the ability of the snares to retain the hairs as well as the degradation of genetic material and the frequency of visitation by individual lynx. However, in this longer time period, a hair snare might capture the hair of more than one animal, which would lead to multiple DNA samples. This could be prevented by using single-sampling hair snares (Bremner-Harrison et al. 2006), but these hair snares are more complex and more expensive. Therefore, their suitability for large-scale monitoring is limited. Another way to prevent multiple DNA samples is to shorten the control intervals, but this is not feasible for large-scale surveys as described above. For lynx in the Bavarian Forest National Park, the longer control intervals of 2 weeks probably would not lead to multiple DNA samples, as indicated by the results of camera trap studies, in which 90% of the cameras were approached only by a single individual over the duration of a winter. In the other 10% of the cases, with one exception, more than 1 month passed before the second individual approached the camera.

Hair snares are expected to be highly practical as a tool for large-scale monitoring projects (Ruell and Crooks 2007; Downey et al. 2007; Weaver et al. 2003). Owing to their comparably low cost and simple production, high numbers of hair snares can be used in a given study area. Because of the large numbers used in field studies, the collection of hair must be as easy and short as possible. To keep their maintenance and handling in the field as simple as possible, we constructed the hair snares only with mechanical components. To be able to use the snares repeatedly and to prevent mixing of DNA samples, which would make it difficult or impossible to positively identify individual animals (Bremner-Harrison et al. 2006) or would lead to wrong identifications, all hair must be completely removed at each sampling. Hairs must therefore be easy to find on the snares, e.g., with contrasting colored carpet, and to extract from the snares in the field. Any remaining, unsampled hairs could be removed from the post by flaming, which is well suited for the wildcat hair snare (Hupe and Simon 2007) and the wire brush hair snare if the carpet element is protected with a pre-cut form.

By conducting the hair snare experiments in enclosures, we were able to control the constancy of several factors that could have affected the tests. The influence of initial tests on subsequent tests was minimized by using new hair snares for each trial and by allowing an intermittent, 4-day period between tests. The placement of the snares 1 m apart was chosen so that the posts as such had the same probability of being used and so that snares were then chosen based only on their physical characteristics. In each test, all hair snares were subjected to site-specific factors, such as weather and scent diffusion. The limited observation area also simplified the video surveillance of the hair snares. However, one major shortcoming of this design could be that the frequency of post use and the amount of hair left are not independent between posts. Since the number of available hairs (or loose hairs) on a lynx is finite, the choice of the lynx to rub against the first post reduces the amount of hair available for other hair snares used thereafter. Also, rubbing against the first post may affect the chances of the lynx rubbing against other posts. However, our study showed that the results are not affected by the research design. First, the video recordings showed that the animals usually rubbed against only one post before leaving the site — in only one case did a lynx rub against all posts, one after the other. Second, we believe that enough loose hair would still be available on the lynx after each rubbing event to ensure that enough hair was deposited on the next post. This is an important point because in the wild the lynx could rub against a natural marking site before rubbing against a hair snare.

In general, keeping lynx in enclosures restricts their activity radius, and captive animals are generally bored, well fed, and always within a short distance of the hair snares. However, owing to the large size and near-natural character (fenced-in forest) of the enclosures used in our study, the conditions approach a natural situation. In addition, we addressed only questions concerning hair collection, which can be tested more reliably in enclosures than, for example, the effectiveness of different kinds of bait (Kendall and McKelvey 2008). In a natural setting captive animals tend to investigate new objects in their enclosures with great curiosity. For this reason, it must be taken into consideration that the hair snares are more attractive to animals living in enclosures than to animals living in the wild, and it can be assumed that rubbing frequency and duration would be higher in enclosures. These considerations, however, do not question our main conclusions, namely whether the hair snares differ in attractiveness and which type of hair snare collects and retains the most hair.

Conclusions

Lynx rubbed against all the types of hair snares tested, but rubbing duration differed. Although lynx hair is very fine and therefore difficult to collect with snares, the wire brush hair snare was effective, collecting more hairs than other snare types during short time periods and retaining more hairs than other designs over 2 weeks. This type of hair snare was also easy to sample. Since the hair of other felids is similar in character to lynx hair, we expect that the wire brush hair snare would also be effective for trapping hair of other felids with a similar body size and most likely also for other mammal species.

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