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The Efficacy of Wire and Glue Hair Snares in Identifying Mesocarnivores

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Abstract

*Track plates and cameras are proven methods for detecting and identifying fishers (*Martes pennanti*) and other mesocarnivores. But these methods are inadequate to achieve demographic and population-monitoring objectives that require identifying sex and individuals. Although noninvasive collection of biological material for genetic analysis (i.e., hair-snaring methods) may help achieve these objectives, they have yet to be evaluated. We incorporated wire- and glue-snares into track-plate enclosures in bait stations deployed at 3 locations in California, USA, in 2002 and 2003 to compare their efficacy. We detected 5 species of carnivores via their tracks, fisher and marten (*M. americana*) most frequently. We collected 96 hair samples, 71 (80%) of which had sufficient DNA to yield a species identification. The wire-snares were more permeable to all species, but both snares were permeable to fishers. Glue-snares were more effective at collecting hair than the wire-snare configuration used. Small species, such as the marten, did not readily leave hair on the wire-snare. Glue was more cumbersome to handle than wire, but, given that it collected more hair and more reliably, we favor use of a glue-snare for fisher surveys. Glue also was effective at collecting hair that was correctly identified as marten on 72% of visits by martens. The hair-snaring method resulted in a 58% and 75% rate of successful identification of fishers that entered the enclosure for wire and glue, respectively. Most failures were due to either insufficient DNA in the sample or no hair snared during a visit to the bait. The success of verifying the presence of a species also was affected when a second species visited the station between check intervals. We believe that changes in laboratory technique can mitigate this problem. Although only 75% of the visits by fishers to glue-snares resulted in hair that yielded sufficient DNA for confirmation, we believe this success rate guarantees a high probability that the presence of a fisher would be confirmed by at least one of their visits to a multiple-station sample unit in which each station is checked several times. A sample of hair from fishers and martens were selected for individual identification, and 9 of the 12 fisher samples had sufficient DNA to identify a minimum of 6 different individuals. Track and genetic methods need not compete for use by carnivore surveyors; each is inexpensive enough when deployed in the integrated unit we tested here to justify their use as companion methods. However, additional innovations will be necessary to increase the number of species that can be detected by track and genetic means at the same location.* (WILDLIFE SOCIETY BULLETIN 34(4):1152–1161; 2006)

Key words

California, carnivore, DNA, fisher, genetics, hair snare, identification, marten, Martes americana*,* Martes pennanti*, noninvasive, population monitoring, track plate.*

The use of noninvasive methods to collect biological material for genetic analysis is becoming a common practice for detecting the occurrence of rare mammals (Woods et al. 1999, Mowat and Paetkau 2002, Schwartz et al. 2004). This approach can provide a tremendous amount of information about distribution, population composition, and even individual identification (Palsbøll et al. 1997, Taberlet et al. 1997), all at a relatively modest cost compared to traditional invasive methods (i.e., capture and handling). Biological samples that have been used as a DNA source include feces (Kohn et al. 1999, Eggert et al. 2003), urine (Hedmark et al. 2004), and hair, collected either from features where it naturally is deposited (Gagneux et al. 1997, Schwartz et al. 2004, McKelvey et al. 2006) or from a device specifically designed to obtain hair from the subject (Woods et al. 1999, Belant 2003).

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We focus on hair-snaring methods here but acknowledge that there are circumstances in which other detection methods, such as the collection of noninvasive genetic samples using trained dogs, may be the most efficient method for detecting the occurrence of mesocarnivores (e.g., Smith et al. 2001, Wasser et al. 2004). Our interest in hair snares stems largely from our desire to add value to an existing survey and monitoring program for fishers (*Martes pennanti*) and American martens (*M. americana*) in California, USA, that currently relies on the systematic deployment of light-weight track-plate enclosures (Zielinski and Mori 2001, Truex 2003, Zielinski et al. 2005). We are interested in determining how we could incorporate the collection of hair samples within the system already used in California.

Tracks are useful for discriminating species (e.g., Zielinski and Truex 1995, Zalewski 1999) and, in some cases, individuals (Sharma et al. 2005, Herzog et al. 2007), but

hair samples are a more reliable method for determining individual identity. Our interest in developing a method for snaring hair was motivated primarily by the need to improve our inventory methods to the point at which we can identify the individuals that visit our baited detection stations. This would allow us to monitor population size directly, via application of mark–recapture methods (Palsbøll et al. 1997, McKelvey and Schwartz 2004, Lukacs and Burnham 2005) rather than indirectly via our current index (proportion of sample units with a detection.)

Before these efficient laboratory genetic methods can be applied, however, a hair-snaring device must be developed that is as reliable as track plates at documenting visits by fishers and, ideally, other mesocarnivores as well. Our goal was to develop an effective noninvasive snare that also was lightweight and portable, easy to assemble, and inexpensive. While many devices may effectively work as snares, here we report on the development of 2 devices and their efficacy.

Materials and Methods

The Snare Devices

We designed and tested 2 types of hair snares: one using barbed wire (modified from Mowat et al. 2001) and one using glue strips (modified from Foran et al. 1997). To test the performance of the hair snares compared with the frequently used sooted track-plate survey method, we built our snare devices to fit within the same type of enclosure used for the latter method (following Zielinski 1995). This allowed us to independently sample species identifications by comparing the results of hair-snare detections from DNA with detections obtained concurrently and independently from track plates placed within the same enclosures.

Our goal was to evaluate and choose the best design for deployment in field surveys using a single enclosure containing either a wire- or glue-snare. However, for the purposes of our experiment, we used paired enclosures. Each snare enclosure consisted of a $25 \times 25 \times 85$-cm box with one of the 2 snare devices placed in the box opening (Fig. 1a). We used lightweight corrugated plastic (Coroplast™; Coroplast Inc., Dallas, Texas) for box construction (J. Ray, Wildlife Conservation Society, personal communication). We then attached an empty, unmodified box, open at both ends, to the front of each type of snare enclosure. We placed a sooted track plate in both the entrance enclosure and the snare enclosure, allowing us to independently verify the identity of species that visited each enclosure and to determine whether the species penetrated the snare device. This combination of paired boxes, one wire-snare enclosure and one glue-snare enclosure, each with an entrance enclosure, was considered a single experimental station (Fig. 1b).

To maximize opportunities for snagging hair, we used "Gaucho" barbed wire (Gaucho®; Bekaert Corporation, Marietta, Georgia) that has 4 points per barb and 7.6-cm spacing between barbs (standard barbed wire has 2 points per barb and 12.7-cm spacing between barbs). Three single strands of wire were cut to 35-cm lengths and inserted in a Z-pattern across the enclosure opening (Fig. 1a) such that no opening between wires exceeded 8 cm in width.

We used glue from commercially available, glue-impregnated cardboard sheets designed to trap mice (Catchmaster®; Atlantic Paste & Glue Co., Brooklyn, New York). These glue sheets are superior to glue trays we used in previous studies because the glue is protected by a paper cover that can be peeled off in the field immediately before use, thus protecting the glue from contamination (R. Schlexer, United States Forest Service, personal observation). We cut the glue sheets into 1.9×20-cm strips and tacked them to a $1.9 \times 3.7 \times 35.2$-cm wood furring slat. We inserted this slat through the sides at the front of the enclosure, about 6 cm from the floor and perpendicular to the long axis of the enclosure, with the glue strip on the underside. We inserted 2 additional slats (without glue) above the glued slat to discourage an animal from climbing over the lowest glued slat (Fig. 1a). We designed the glued slat to pivot upward on one end an additional 2 cm to allow for the passage of individuals or species that vary in size.

We baited each snare enclosure with a single piece of raw chicken and a commercial scent lure ("Gusto"; Minnesota Trapline Products, Pennock, Minnesota) and sealed it at the rear with hardware cloth, forcing the animals to enter the enclosure through the snare device. We placed wire and glue enclosures (with their attached entrance enclosures) side by side and fixed them firmly to the ground with wooden stakes and baling wire, to constitute a single experimental station (Fig. 1c). We checked stations every other day for approximately 2 weeks.

When we visited each station, we checked the track plates for tracks and identified them using a key (Taylor and Raphael 1988) and a local reference collection. We recorded the type of snare enclosure that was visited (glue or wire) and whether the tracks were in the entrance enclosure only or in both the entrance and snare enclosures. If hair was present on barbed wire, we removed the entire strand of wire and cut the barb(s) with hair from the strand and placed it into a clean, labeled transfer container (35-mm film container) with a small amount of silica desiccant to retard DNA degradation. If hair was present on a glue strip, we cut the portion of the strip with hair from the slat and placed it in a separate container. We collected all hair on snares and placed multiple tufts from the same device in separate containers. We exchanged the wire or glue strips with uncontaminated versions and replaced the bait and track plates as needed. We stored all sample vials at room temperature until they could be sent to the laboratory for DNA extraction and analysis, a period that never exceeded 8 weeks.

The Study Areas

We established 28 experimental stations in 3 areas of California: the Hoopa Valley Indian Reservation, the Sierra National Forest, and Lassen Volcanic National Park (Fig. 2). Fishers are known to occur at the first 2 areas; martens were unlikely to occur at the first 2 areas but were the target species at Lassen National Park. On the Hoopa Valley

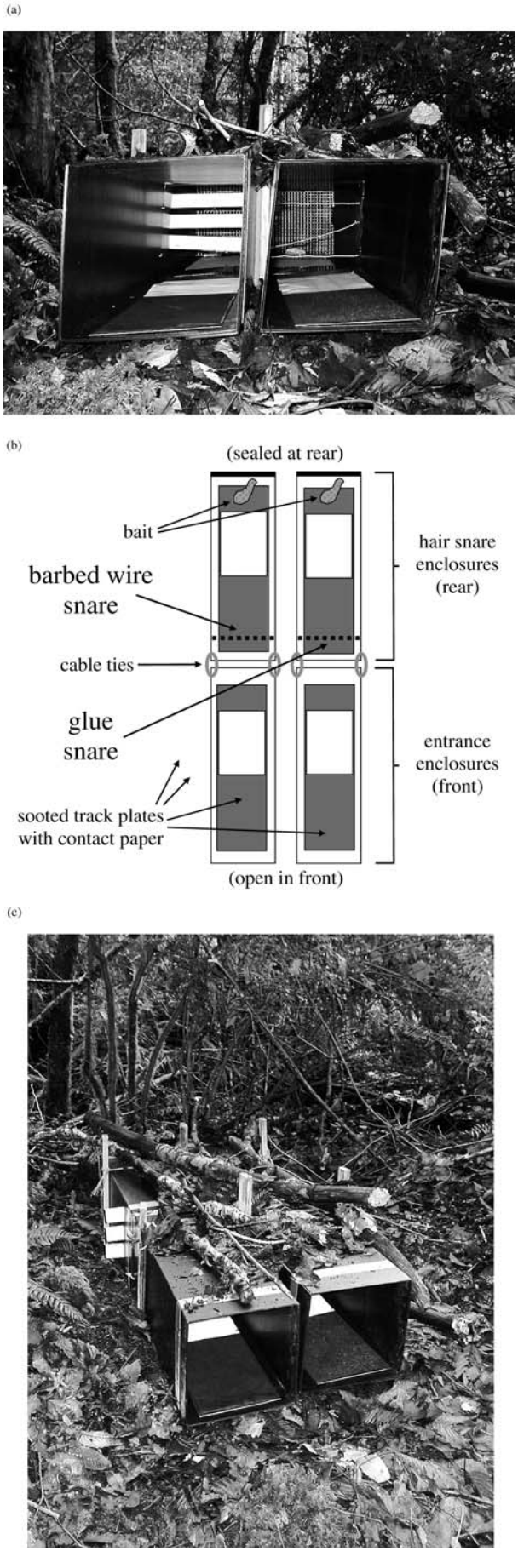

Figure 1. (a) Front view of wire- and glue-snare enclosures showing the orientation of hair-snaring components. (b) Schematic of a single experimental station. (c) Overall view of a single experimental station in situ, consisting of one wire-snare enclosure and one glue-snare enclosure, each with an attached entrance enclosure.

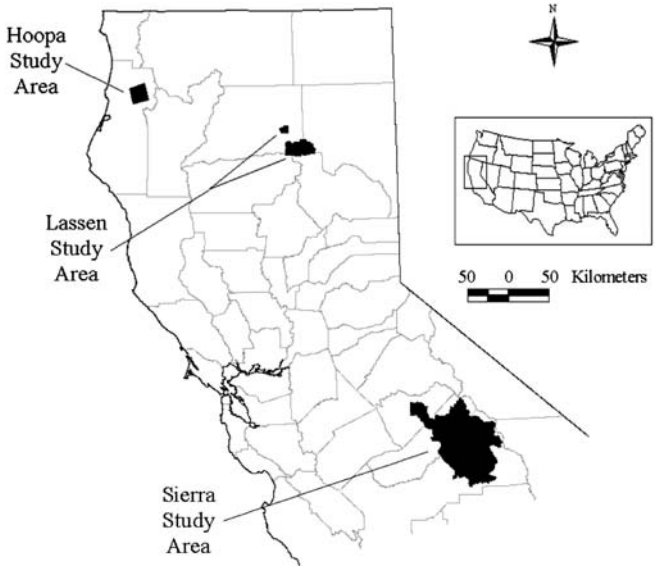

Figure 2. The 3 study areas (in black) where hair-snare testing was conducted, California, USA, 2002–2003. Interior lines illustrate the boundaries of California counties.

Indian Reservation, in northwestern California (hereafter Hoopa), we ran 6 stations from 9–23 January 2002. We placed stations at approximately 2-km intervals along roads from 240 to 850 m in elevation and checked them every other day for 12 days. Between 25 September and 28 October 2002, we ran 12 stations on the Sierra National Forest, in the central Sierra Nevada Mountains (hereafter, Sierra). We placed stations at points on an existing grid established to collect hair from fishers and checked them every other day for 12 days. Elevations ranged from 1,100–2,100 m. Our third area comprised locations on Lassen Volcanic National Park and on Lassen National Forest and the associated Thousand Lakes and Caribou wilderness areas in the southern Cascade Mountains (hereafter Lassen). We checked 10 stations every other day for 14 days from 13–25 September 2003. We placed stations at locations where martens had been detected during previous surveys (Zielinski et al. 2005) at elevations between 1,860 m and 2,200 m.

Genetic Methods

Species identification.—We brought hair into a satellite genetics laboratory in a separate building from the main genetics laboratory. This satellite lab was never used for DNA extraction from tissue or DNA amplification, thus minimizing contamination possibilities. We extracted hair using the QIAGEN DNEASY Tissue Kit (QIAGEN Inc., Valencia, California) with modifications for hair extractions.

We optimally chose 10 hairs with follicles for DNA extractions. If <10 hairs were present in the sample, or follicles were not present, we used what hair was available. We used a 16S mitochondrial DNA restriction digest test to exclude ursid, felid, and canid samples (Mills et al. 2000, K. L. Pilgrim, United States Forest Service, unpublished data). We further identified canids to species using a cytochrome *b* test (Paxinos et al. 1997). We amplified all candidate mustelid samples at cytochrome *b* and used a series of restriction enzymes following Riddle et al. (2003) to identify species.

Individual identification.—We selected 12 samples that had been genetically identified as fisher and 14 that had been identified as marten to determine the identity of individuals. We selected these samples from among study sites and disparate stations within study areas to maximize the possibility that they represented different individuals. Using these samples we amplified 6 nuclear microsatellites (Ma1, Ma2, Ggu234, Ggu216, Ggu101, and Lut604; Dallas and Piertney 1998, Davis and Strobeck 1998, Duffy et al. 1998) following published protocols, but with modifications for hair samples to identify the minimum number of individuals alive. We amplified DNA from hair samples a minimum of 3 times at each microsatellite locus to ensure consistency of genotypes (Taberlet et al. 1996, Schwartz et al. 2004); we ran those samples that did not provide concordant genotypes additional times or deemed them of too poor quality to provide individual identification.

Analysis

We evaluated the efficacy of each snare type using both quantitative and qualitative criteria. Our first measure of interest was snare "permeability," which was the proportion of times that the tracks of a species appeared on the track plate in the entrance enclosure and also appeared on the track plate in the snare enclosure. This provided an indication, for each species, of how readily they passed through each of the devices to get to the bait. The second measure for comparing the types of snares was on the basis of "effectiveness," which we defined as the proportion of times that tracks of a species were present in the snare enclosure and there was also detectable hair on the snare in that enclosure. This provides an indication of how successful the devices are at securing hair from a subject that enters the enclosure. Although we focused our efforts on developing a method for fishers and martens, we also compared the devices on the basis of the number of species of mammals that were detected via their hair.

We also compared the devices on the basis of quantity and quality of DNA collected, and accuracy of species identification from DNA analysis. The laboratory team was "blind" to the information about tracks that appeared in the snare enclosure and to the geographic location of the station from which hair was collected. Thus, identities of the species that were determined on the basis of a restriction enzyme assay could be compared against the independent track identifications. Finally, we assessed the cost and compared ease of use for each snare type.

Results

Species Detected Using Tracks

We deployed 28 experimental stations among the 3 study areas, for a total of 316 snare-nights (158 checks × 2 days between each check; Table 1). Based on their tracks, we detected 5 species of mesocarnivores (Table 1): fisher, marten, gray fox (*Urocyon cinereoargenteus*), ringtail (*Bassariscus astutus*), and western spotted skunk (*Spilogale gracilis*). A detection occurred when the track of a species was verified to occur in an enclosure when it was checked. Fishers and martens were the species whose tracks were detected most frequently (30 and 15 detections, respectively; Table 1). In almost all occasions when a species' track was detected at the wire-snare enclosure, tracks from that same species were also present in the glue-snare enclosure. The exception was gray fox, which did not visit the glue-snare enclosure on 8 occasions when it had visited the companion wire-snare enclosure.

Instances where the tracks of 2 or more species were detected in the back of the same snare were uncommon (8 of 158 snare-nights) and occurred only in the Hoopa study area. We detected fisher and gray fox by tracks at the same station during the same check on 8 occasions: 6 times at wire-snares and 2 times at glue-snares. This provided an opportunity to determine how successful a genetic technique would be at detecting visits by >1 species on a single occasion.

Species Detected Using DNA

We collected 96 hair samples; 41 (43%) from wire enclosures and 55 (57%) from glue enclosures. The DNA analysis resulted in the identification of 5 species of carnivores: fisher ($n = 47$), marten ($n = 14$), gray fox ($n = 9$), ringtail ($n = 1$), and black bear (*Ursus americanus*; $n = 1$). Twenty-five of 96 hair samples did not yield an identification because either the hair was not discovered or discovered on the outside of the container when the transfer container was opened ($n = 6$; 6%) or because DNA could not be amplified from the sample ($n = 19$; 20%). The cause of DNA failing to amplify could be due to the collection of shed hair, hair fragments without follicles, or unknown reasons.

Comparisons: Wire versus Glue

The number of hairs snared during a single animal visit to a snare enclosure varied from one to several dozen. On a number of occasions (7 for wire and 9 for glue), we collected 2 tufts of hair from the same snare at the same check. Typically, barbed-wire snares collected fewer hairs than glue-strip snares. When we placed a barb with only a few hairs attached in a transfer container, the chance that these hairs would be lost during handling and transfer was increased.

Snare permeability.—Behavior toward the snare enclosures varied by device and species (Table 2). For wire-snares, fishers, martens, ringtails, and spotted skunks continued into the snare enclosure every time they entered the entrance enclosure. Gray foxes continued into the wire-snare

Table 1. Carnivore detections via tracks at experimental stations on the Hoopa, Sierra, and Lassen study areas, California, USA, 2002–2003. A "check" is a 2-day period between visits by the investigator. Tracks at the wire- or glue-snare, or both, represent a single detection. Numbers in parentheses are percentages.

	Study area			
	Hoopa	**Sierra**	**Lassen**	**Total**
No. of checks	36	69	53	158
No. (%) of track detections				
All carnivores	26 (72)	15 (22)	15 (28)	56 (35)
Fisher	24 (67)	6 (9)	0	30 (19)
Marten	0	0	15 (28)	15 (9)
Gray fox	9 (25)	2 (3)	0	11 (7)
Ringtail	0	4 (6)	0	4 (3)
Western spotted skunk	0	3 (4)	0	3 (2)

enclosure on only about half of the occasions (55%). For glue-snares, only ringtails continued into the snare enclosure every time they entered the entrance enclosure. Glue-snare permeability for other species ranged from 86% (marten) to 50% (spotted skunk; Table 2). In several cases hair was collected from wire- and glue-snares even though there were no tracks in the snare enclosure, perhaps because hair could be snared from animals that stuck only their heads into the enclosure. On one occasion a fisher and a gray fox negotiated a wire-snare at the same enclosure but neither left hair.

Snare effectiveness.—Glue-snares were more effective at capturing hair than wire-snares (Table 2). Wire-snares were most effective at snaring hair from gray foxes and fishers (100% and 90%, respectively), but virtually ineffective at snaring hair from martens (7%), probably due to wide spacing between barbs relative to their body size. Glue-snares were 92–100% effective at capturing hair from all 5 carnivore species (Table 2).

DNA quality.—We sent 96 samples to the laboratory, of which 90 contained hair (vs. vegetation or no hair). Identification to species was possible for 71 of 90 samples (78.9%), with the majority of failures due to inadequate or poor-quality DNA (Fig. 3). This is similar to amplification rates observed in other noninvasive hair surveys (K. L. Pilgrim et al., unpublished data, McKelvey et al. 2006). The proportion of samples that were incapable of being amplified did not differ whether the sample came from wire or glue

Table 2. Permeability and effectiveness of wire- and glue-snares for fishers,[a,b] martens,[c] gray foxes,[a,b] ringtails,[b] and western spotted skunks,[b] as tested in California, USA, 2002 and 2003.

	Permeability[d]					
	Wire			Glue		
	No. of tracks			No. of tracks		
Species	**Entrance enclosure**	**Snare enclosure**	**% permeability**	**Entrance enclosure**	**Snare enclosure**	**% permeability**
Fisher	29	29	100	29	24	83
Marten	15	15	100	14	12	86
Gray fox	11	6	55	3	2	67
Ringtail	4	4	100	3	3	100
Spotted skunk	3	3	100	2	1	50
	Effectiveness[e]					
	Wire			Glue		
Species	**Tracks present**	**Hair present**	**% effectiveness**	**Tracks present**	**Hair present**	**% effectiveness**
Fisher	29	26	90	24	22	92
Marten	15	1	7	12	12	100
Gray fox	6	6	100	2	2	100
Ringtail	4	3	75	3	3	100
Spotted skunk	3	2	67	1	1	100

[a] Hoopa study area, 9–23 Jan 2002.
[b] Sierra study area, 25 Sep–28 Oct 2002.
[c] Lassen study area, 13–25 Sep 2003.
[d] Permeability is the proportion of times that the tracks of a species appeared on the track plate in the entrance enclosure and also appeared on the track plate in the snare enclosure.
[e] Effectiveness is the proportion of times that the tracks of a species were present in the snare enclosure and there was also detectable hair on the snare in that enclosure.

(Fig. 3), even though the glue-snares regularly collected more hair per sample than the wire. Thus, both methods appear to produce samples that have similar rates of success at achieving species identification from the hair they collect.

Other factors: cost and ease of use.—We found no evidence that either of the snare devices restrained or harmed any of the species detected. The enclosures for both types of snare were lightweight, portable, and easy to set up under a variety of conditions. The cost for a single snare enclosure, including 1 Coroplast box, hardware cloth back with 4 cable ties, 4 stakes (without a track plate), and bait and lure, was about US$4.37. The cost of wire strands (3 needed per enclosure at $0.102 each) was greater than that for glue strips (1 needed per enclosure at $0.089 each). Handling glue-snare material, which was very sticky, was more challenging than handling wire, both in the field and in the laboratory. Particularly cumbersome was removing and cleaning hair from glue-snares, which involved using a xylene wash (Foran et al. 1997) prior to DNA extraction. This step required almost twice as much handling time in the laboratory as removing hair from wire.

Species Identification: Tracks versus DNA from Hair

Species identity from tracks was rarely uncertain in our study areas because it was usually confirmed on the spot and, unlike genetic methods, it is not influenced by transport, handling, processing, or intermediate steps necessary before identification can occur. Furthermore, ample track-identification work has been conducted in this region, providing us with both a reference collection of tracks and experts at identifying tracks. Thus, success of the genetic method was measured by the proportion of times that the visitation by a species to the snare enclosure (verified by tracks) resulted in the identification of the same species from its hair (Table 3).

For fishers the hair-snaring method resulted in a rate of successful identification of 58% and 75% for wire and glue, respectively. Most of the failures were a result of insufficient DNA in the sample or, particularly for wire, samples so small (i.e., a single hair or hair fragment) that they were lost in transport or found on the outside of the container. Failures occurred at 10% and 6% (wire and glue, respectively) of the opportunities to verify visits by fishers because the animal visited but no hair was collected. Almost one-quarter of the fisher failures with the wire method occurred when tracks indicated that fisher and a second species (in this case, gray fox) visited the snare enclosure, but the hair sample(s) resulted in the identification of gray fox only. In the 8 occasions when fisher and gray fox were identified by their tracks to have visited the same snare enclosure (6 in wire and 2 in glue-snare enclosures), there was never an occasion when both species were confirmed via the DNA from snared hair, primarily because the laboratory initially was only looking for single species when analyzing the hair. In 4 of these 8 occasions (50%) fox was the only species verified via DNA analysis and in 1 of the 8 occasions (12%) fisher was the only species verified via DNA analysis; the remainder had either no hair or insufficient DNA for analysis. Glue-snared hair was more reliably identified as fisher than wire-snared hair because 1) there were fewer occasions when fisher and a second species had visited a glue-snare enclosure during a single check period, and 2) the glue snared larger quantities of hair than the wire. When fishers were the only species to visit an enclosure and sufficient DNA was available for analysis, they always were verified via the DNA method. When a fox and fisher visited the enclosure, however, the probability that the fisher would be identified via its hair dropped to 12%, representing a potentially significant loss of information where gray foxes are common.

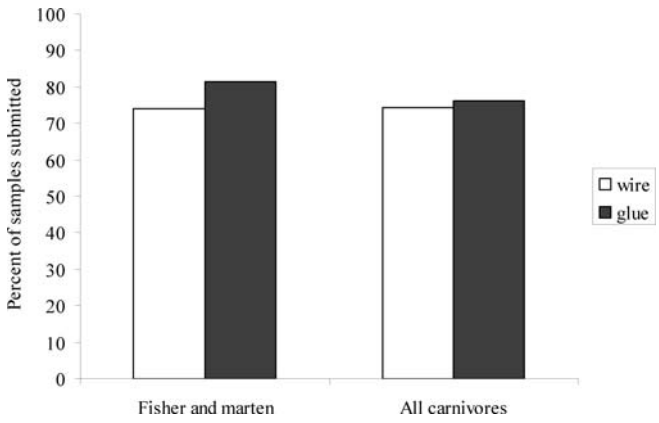

Figure 3. Percentages of fisher and marten samples, collected in California, USA, 2002–2003, and all carnivore samples submitted for analysis that had sufficient DNA, based on our restriction enzyme species test, to determine species identity.

Martens did not afford similar opportunities for comparison because the wire-snares were so permeable to this species that hair was rarely collected using this method (Tables 2, 3). Glue-snares, however, collected hair that was correctly identified as marten 13 out of 18 opportunities (72%); failures were primarily due to insufficient DNA in the sample and not due to misidentification of the DNA (Table 3). There were fewer total opportunities to detect gray foxes, but wire was the only method to verify them via the DNA in their hair (Table 3). Ten of 19 opportunities to identify gray fox from hair failed due to insufficient DNA and the fact that gray fox was the second of 2 species to visit a snare and was not identified in the hair sample.

We had 5 circumstances of animal visits to our snares that are difficult to explain. In one instance we identified both fisher and gray fox DNA from a single hair sample (consisting of multiple hairs) due to a "mixed" DNA sample resulting from both species' hairs, but we found no gray fox tracks at that enclosure. In a second, a black bear detection via DNA from hair occurred at a wire-snare where only spotted skunk tracks were found, possibly because the bear was able to reach between the entrance enclosure and the snare enclosure. Third, at a glue-snare where we found only spotted skunk tracks, we collected hair that was identified via DNA as fisher, even though we found no fisher tracks.

Table 3. Comparison between track and DNA identification of species of mammalian carnivores detected from hair on either wire or glue-snares in California, USA, 2002–2003.

	Wire					Glue				
	Fisher	**Marten**	**Gray fox**	**Ringtail**	**Spotted skunk**	**Fisher**	**Marten**	**Gray fox**	**Ringtail**	**Spotted skunk**
Opportunities to verify ID[a]	31	15	15	4	2	36	18	4	3	2
Successful hair ID[b]	18 (58)	1 (7)	8 (53)	0	0	27 (75)	13 (72)	0	1 (33)	0
Failed hair ID[c] due to:										
No hair collected	3 (10)	14 (93)	1 (7)	2 (50)	1 (50)	2 (6)	1 (6)	0	0	0
Insufficient DNA	3 (10)	0	0	2 (50)	1 (50)	3 (8)	4 (22)	2 (50)	2 (67)	1 (50)
No hair in container	4 (12)	0	0	0	0	1 (3)	0	0	0	0
Multiple species	3 (10)	0	6 (40)	0	0	3 (8)	0	2 (50)	0	0
Misidentification	0	0	0	0	0	0	0	0	0	1 (50)[d]

[a] "Opportunities to verify ID" is the number of times there was a track in the snare enclosure, indicating that an individual of the species encountered the snare.

[b] "Successful hair ID" is the number (%) of times the hair-snare method collected a sample from which DNA analysis resulted in a determination that agreed with the track identification.

[c] "Failed hair ID" is the number (%) of times the hair snare failed to produce results that did not agree with the track identification, for the reason listed.

[d] Spotted skunk misidentified as fisher.

In 7 cases (1 wire, 6 glue), we collected hair identifiable to species (4 fisher, 1 marten, 2 gray fox) from snares where the animal only left tracks in the entrance enclosure, indicating that the snares may occasionally be effective even when the animal does not completely enter the enclosure or accesses the snare through an unintended entrance.

Individual Identification

All individuals identified differed in genotype at a minimum of 2 loci. Seven fisher samples from the Hoopa study area and 2 samples from the Sierra study area provided adequate DNA for uniquely identifying individuals. This represented a minimum of 4 and 2 individual fishers from each study area, respectively. The 14 marten samples yielded genotypes on 11 samples, which we determined to be from 3 individuals.

Discussion

The methods we tested were effective at snaring and identifying hair from most of the species of carnivores that entered the enclosures. However, the relative effectiveness of wire and glue differed within species and the superior snare method also differed among the various species that entered the enclosures. We directed the methods primarily toward capture of hair from fishers and, secondarily, martens. Our hope was that a single design would be equally effective for both of these species and that, during the process, the device would also detect as many other mesocarnivores as possible. Given the heightened interest in the conservation of fishers (United States Department of Interior Fish and Wildlife Service 2004), however, any method developed must succeed with fishers as the primary target species.

"Success" of the method at surveying fishers can be viewed in a number of ways. In the most proximate sense, both the glue- and wire-snares were permeable to most (>80%) of the fishers that entered them and they snared hair from most (>90%) of them as well. In this regard snaring methods were nearly as successful as track-plate methods at collecting evidence that can be used to determine the presence of a fisher. Success decreases, however, when considering the percentage of the tufts of hair that yielded sufficient quality DNA to determine whether the hair that was snared was from a fisher. The success at identifying fisher hair to species, when fisher tracks were in the snare enclosure, was 58% for wire- and 75% for glue-snares.

Although a 58–75% success rate would appear to be a significant shortcoming, it may not affect the success of detecting fishers if hair snares are used in sample designs that resemble those currently used for track plates. If, for example, hair snares were to be deployed in multiple-station sample units (as are track plates in California; e.g., Truex 2003, Zielinski et al. 2005), a single detection at any one station is sufficient to document presence at the sample unit. Thus, the probability of confirming at least one fisher visit to a sample unit would be calculated by estimating the expected number of visits by fishers to a multiple-station sample unit and compounding the per-visit probability by the expected number of visits. For example, a 6-station sample unit (Zielinski et al. 2005) provides 48 opportunities to detect a fisher if the stations are checked every 2 days for a 16-day period. Previous data indicate that when a fisher is detected at a 6-station sample unit, it is detected on an average of 5 of the 48 opportunities (Zielinski et al. 2005). If the probability of verifying each fisher visit, via genetic means, is 0.65 (average of glue and wire), then the probability of failing to confirm identity at any one visit is 0.35 and the probability of failing to confirm over 5 visits is a reassuring 0.005 (0.35^5). Using the glue-snare success rate (75%) reduces the probability further to 0.0009. However, if deployed in single-station sample units, a 65%, or even 75%, rate of successful identification from a snare would likely be much less than the success of identifying tracks as fisher from a single track-plate station.

We did not fully explore the implications of the hair-snaring methods at achieving the ultimate goal for fisher monitoring: estimating trend in population size by identifying individual fishers. The current work, however,

demonstrated the possibility of achieving this goal in that most of the fisher hair samples yielded sufficient DNA to assess individual identity. Additional microsatellite primers are in development to optimize a system for individual fisher identification in each of our study areas (M. Jordan, University of California-Berkeley, unpublished observation, M. K. Schwartz, United States Forest Service, unpublished observation). With these new tools, we should be able to readily distinguish when multiple individuals left hair samples. In this study, we conducted the laboratory work under the expectation that each tuft of hair was from a single species, yet it was entirely possible that 2 species left hair on the same barb, or in the same location on the glue. With what we now know about the potential for multiple visits, we have revised our laboratory protocols to improve the detection of multiple species visiting the snare. Primarily this has involved obtaining a reference collection of the possible species that may visit a snare and understanding the restriction digest pattern of each of these species given our mustelid assay. Furthermore, knowing that multiple visits are possible, we can use gross morphology to separate hairs and run each type of hair separately.

The ideal solution, however, would be to develop a hair-snare method that would not allow >1 individual to enter. Belant (2003) offered an answer to this problem by developing a snare using a curry comb attached to a modified live-trap. This ingenious solution needs additional testing for its effectiveness and permeability. However, the unit cost (approx. US$64.00/unit) far exceeds the approximately $4.00/unit cost for our snares, making it much more expensive to include in the regional design we envision. Furthermore, sufficient testing would be necessary to be certain that the device would not accidentally confine a fisher (or any other species), as was reported for a snowshoe hare (*Lepus americanus*; Belant 2003). Other single-visit devices have been considered (i.e., a stretched spring that snares hair when it quickly recoils [M. Higley, Hoopa Tribal Forestry, personal communication]; a one-way door on a baited enclosure [K. Heinemeyer, Round River Conservation Studies, personal communication]) but none have been subjected to rigorous testing.

Like fishers, martens are a species of keen conservation interest, particularly in the coastal ranges of the Pacific states and the upper Midwest (Zielinski et al. 2001, Woodford 2005). The success rate we achieved for verifying the visits by martens was less than for fishers. Although martens and fishers seem equally willing to pass through both snaring devices, the effectiveness of the wire-snare was very poor for martens (7%). And although this may be remedied by shortening the distances between strands of wire, the effect of this modification on the permeability of the wire-snare to fishers would need to be reevaluated. The glue-snare, in contrast, was about equally effective at detecting martens and fishers, with successful identification occurring in 72% and 75% of the opportunities, respectively, and represents the best option for snaring hair from both fishers and martens. Other snaring devices have been used with carnivores (e.g., metal gun-cleaning brushes [J. Copeland, United States Forest Service, personal communication]) and these should be tested for their snaring effectiveness as well.

The difficulty of accommodating 2 species, fishers and martens, in a wire-based design highlights a larger problem with hair-snaring when compared to track-plate and camera methods. Because of the long history of using track plates (Barrett 1983, Zielinski 1995) and camera methods, we are able to detect multiple nontarget species with these tools, which often were missed by the snares. For example, note the low permeability of both snare types for gray fox (55% and 67% for wire and glue, respectively) compared to fisher (100% and 83%). Only 53% of the opportunities to detect gray fox via their hair in wire-snares resulted in success, 0% for glue, although foxes may have been hesitant to fully enter our 2-box system and may be more amenable to snares that lack an entrance box. Track plates detect species as large as black bears and as small as shrews. And, although the means for distinguishing pairs of similar species have been developed for some pairs (i.e., fisher vs. marten; Zielinski and Truex 1995) but not others (e.g., long-tailed weasel [*Mustela frenata*] vs. short-tailed weasel [*Mustela erminea*]), track plates currently are a more effective multiple-species survey tool. However, we can envision using multiple snare types at a site (e.g., a felid-detection pad, a snare box, and a bear snare), which would detect more species than our current snare used alone. Alternatively, further snare development may be able to produce a more omnibus snare.

Fortunately, it currently is feasible to use both the hair snare and the track plate simultaneously without incurring significant added expenses. Thus, in an area like ours where reference collections and discrimination algorithms are available, we can obtain species identification relatively easily, but, if hair were also snared, the genetic data could be used to confirm species' identity when tracks are ambiguous. We caution, however, that the benefits of track plates hold only when reference collections and expertise are sufficient to identify species correctly. The training necessary to achieve this level of accomplishment should not be underestimated.

Although track plates (and cameras) are more discriminating in the species that are readily detectable, neither of these methods can achieve the goal of estimating the population size for target species. This is the significant advantage that hair-snaring genetic methods hold over traditional detection methods. Since our experiments were conducted, we have been deploying wire-snares in the northern United States Rocky Mountains and have been very successful at using the hair to identify individual animals. In fact, in Idaho we have been able to use these hair snares to augment winter fisher home-range estimates, mostly obtained through radiotelemetry.

The goal of this study was to assess a tool for conducting fisher and marten surveys. However, it appears that if conducting a multiple-species survey is the only goal, the use of traditional track-plate or camera methods will provide the best opportunity for success because the only limits to the

number of species that can be detected are 1) the size of the enclosure (if an enclosure is even necessary; see Zielinski [1995] for a non-enclosed track-plate method), 2) the relatively small number of pairs of species that are indistinguishable via their tracks or in photographs, and 3) the natural inter- and intraspecific variation in willingness to approach a bait or lure. However, if the demands on information exceed simple species identity and the goal is to produce a state-of-the-art population-monitoring program for one or a few species of interest, then hair snaring should be the overwhelming choice. Furthermore, with future snare development or the addition of multiple types of snares at a site, both methods may prove useful for multispecies inventory. For instance, in our Idaho, USA, work, we have used the wire hair snare to detect woodrats (*Neotuma* sp.), red squirrel (*Tamiasciurus nudsonicus*), lynx (*Lynx canadensis*), bobcats (*Lynx rufus*), fisher, marten, coyotes (*Canis latrans*), mountain lions (*Puma concolor*), wolves (*Canis lupus*), bears, and beaver (*Caster canadensis*). In addition to the possibility of estimating population size (e.g., Paetkau 2003, Schwartz et al. 2004, Bellemain et al. 2005), this method also can be used to identify sex (yielding population sex ratios), estimate gene flow, determine relatedness, detect historical or contemporary genetic "bottlenecks," and address other population genetic questions (e.g., Manel et al. 2003).

We embarked on the current project as an important step toward developing a method to estimate population size in fishers. Thus, the fact that the glue method had a higher success rate (75%) than the wire method (58%) would argue for adopting the glue method for our monitoring program. Glue collected more quantity of hair than wire, which resulted in less chance that single hairs were lost during processing. However, improved methods for handling individual hairs from wire-snares (e.g., placing distal ends of hairs on tape and enclosing them in an envelope) could significantly reduce the chance that individual hairs are lost during transfer.

Glue also had a slight edge in effectiveness and in the proportion of samples for which sufficient DNA was present. And although glue-snares were less permeable to fishers (83% vs. 100% permeability) and cost a bit more, the only drawback is the difficulty of handling the glue when deploying it in the field and when removing hair from it in the laboratory. Glue also was effective at snaring marten hair, and the availability of new products to clean hair (Goo Gone; Magic American Corporation, Beachwood, Ohio) significantly reduces the inconvenience of this snare method. The inconvenience of the glue method may be offset, somewhat, by the fact that glue-snares also had higher success rates at identifying marten visits than the wire-snare used here.

In summary, when fisher is the only target species and when hair snares are deployed in multiple-station sample units, the success of the 2 snare methods is quite similar, especially during the winter season where they were tested here. We did not, however, include the myriad of other potential hair-snaring methods in our experiment, a number of which probably merit additional testing. Similarly, new and improved genetic methods have increased amplification rates (e.g., nested polymerase chain reaction; Bellemain et al. 2005) and they should be developed for small mammalian carnivores to improve the effectiveness of genetic methods to conduct surveys and to estimate their population sizes.

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