Tools and Technology Article

Hair-Trap Efficacy for Detecting Mammalian Carnivores in the Tropics

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ABSTRACT Direct studies of mammalian carnivores are challenging due to the animals' secretive nature and the high costs associated with their capture and handling. Use of noninvasive hair sampling to survey these reclusive species has great potential as an alternative, with wide applicability in ecology and conservation. Hair-trapping has been extensively used for focal studies of temperate mammals, but its use and applicability as a means to survey mammals in tropical environs has never been addressed. We evaluated the effectiveness of 2 hair-trap types and 2 scents along an elevational gradient within El Cielo Biosphere Reserve (ECBR, Mexico) to detect presence of carnivores. Hair-traps that used roofing nails as a hair-collecting surface collected more hairs and detected a greater number of species than did hair-traps that used velcro strips. Different scent treatments (commercial fragrance and catnip oil) did not differ for these same variables. Of successful nail hair-traps, 60% collected ≥20 hairs (max. = 439), providing enough material for DNA analyses. Hair-trap surveys detected 74% of the potential target mammal species at ECBR with only 19 days of field effort. Developing countries have limited budgets for biodiversity monitoring and hair-traps compare favorably with other methods with a high cost–benefit ratio. Hair-traps are inexpensive, portable, can be made with over-the-counter materials, and can be successfully used to collect data applicable to population and genetic studies of tropical carnivores. (JOURNAL OF WILDLIFE MANAGEMENT 72(6):1405–1412; 2008)

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Densities of most medium and large carnivores are low and require large areas of pristine habitat for their existence. Many of these species are endangered and, as such, are prime candidates for monitoring programs. Although national or regional strategies based solely on single species have limited use in biodiversity preservation, protection of these charismatic species provides a tangible goal that can serve as a flagship for conservation campaigns (Andelman and Fagan 2000, Walpole and Leader-Williams 2002). Moreover, many large mammals are apex predators and their status can show early warnings of ecological decline (Niemi and McDonald 2004). Therefore, the ability to have practical, reliable, and cost-effective methods to detect carnivores is a valuable asset for ecology and conservation studies (Voss and Emmons 1996). The nocturnal and secretive behavior of carnivores makes direct studies difficult or impossible to conduct (Aranda 2000) so indirect techniques (camera-traps, track-plates, scent stations, hair-traps, and genetic identifications from scats) are needed to study these taxa (Zielinski and Kucera 1995, Wilson et al. 1996, Foran et al. 1997, McDaniel et al. 2000, Wasser et al. 2004). Camera-traps can detect rare tropical species but their use in tropical areas is constrained by high cost and availability (Sanderson and Trolle 2005). Track-plates and scent stations need arid conditions and adequate substrates, whereas track-plates are negatively affected by rainy weather (Zielinski and Kucera 1995, Harrison 1997). Hair-snaring has a great potential because capture of individuals is not required, cost is low, animals are not harmed, and transport to remote areas is easy.

Hairs can reliably be identified to species by examination of microscopic characters (Moore et al. 1974) or genetic methods (Foran et al. 1997). Noninvasive hair sampling can provide genetic data, which it is not obtained with most other detection methods. Although it is possible to obtain genetic material from one hair (Pfeiffer et al. 2004) it is preferable to have ≥20 hairs to undertake DNA extraction (J. Maldonado, National Zoological Park, personal communication). In temperate environments hair sampling has been used successfully to detect black and brown bears (*Ursus americanus, U. arctos*; Woods et al. 1999; Beier et al. 2005), American marten (*Martes americana*; Foran et al. 1997; Mowat 2006), lynx (*Lynx canadensis*; McDaniel et al. 2000, Schmidt and Kowalczyk 2006), San Joaquin kit fox (*Vulpes macrotis mutica*; Clark et al. 2002–2003; Bremner-Harrison et al. 2006), and bobcat (*Lynx rufus*; Harrison 2006). Ocelots (*Leopardus pardalis*), a neotropical species, have been studied in south Texas, USA, using hair-traps (Weaver et al. 2005), but effectiveness and applicability of hair-traps to document carnivore presence has never been evaluated in tropical settings.

There are many mechanical means of collecting hairs (Valderrama et al. 1999, Belant 2003, Beier et al. 2005, Bremner-Harrison et al. 2006, Ruell and Crooks 2007). Applying a scent to a hair-collecting surface can induce many mammals to rub on the device, thus leaving hairs in the process (Reiger 1979, Turbak 1998, McDaniel et al.

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2000). Attractiveness differs among scents and not all taxa respond in the same manner (Reiger 1979, Mellen 1993, Harrison 1997). We evaluated the efficacy of 2 hair-trap types and 2 scents to detect a wide range of mammal species along an elevational gradient at El Cielo Biosphere Reserve (ECBR) in Tamaulipas, México.

STUDY AREA

We conducted field work at the 144,500-ha ECBR, located in Tamaulipas, northeastern México between 22°55′30″–23°25′50″N and 99°05′50″–99°26′30″W. The Gulf Coastal Plain delimited the east boundary of ECBR (200 m elevation). To the west, the Sierra raises rapidly to 2,200 m and descends into the Mexican Central Plateau (Martin 1955, Puig and Bracho 1987). The reserve comprised 4 major vegetation zones along its elevational gradient (Fig. 1): Tropical Subdeciduous Forest (TSDF), Cloud Forest (CF), Pine–Oak Forest (POF), and Xerophitic Scrub (XS). We conducted sampling on the east-facing slopes at the southern portion of the reserve covering 3 major vegetation zones (TSDF, CF, and POF) plus an agricultural area outside the reserve boundary (coastal plain or CPV). At TSDF sites (200–800 m) most tree species had tropical affinities, average canopy height was 20 m, and a dense understory was present. Mean annual temperature was 22.8° C and total annual precipitation was 1,852 mm (Puig and Bracho 1987). Cloud Forest sites (800–1,400 m) had a mix of tree species of neotropical and temperate origins with a canopy that reached to 30 m. This dense mixed forest had an abundance of vines, epiphytes, and nonvascular plants that existed due to the high relative humidity present year-round. Mean annual temperature was 13.8° C and total annual precipitation was 2,522 mm (Puig and Bracho 1987). Finally, POF (1,400–2,200 m) was more open than neighboring CF, with an average canopy of 20 m and with few vines and epiphytes (Puig and Bracho 1987). Mean annual temperature at these elevations was 15° C (Martin 1958). Mammalian fauna of ECBR at the vegetations zones we sampled consisted of 21 medium and large mammal species of both Neartic and neotropical affinities (Vargas-Contreras and Hernandez-Huerta 2001). This wide range of target species along a variety of environmental conditions made an adequate set to test effectiveness of hair-traps to detect mammalian carnivores.

METHODS

Hair-traps consisted of 10 × 10-cm pieces of outdoor carpet with either velcro or nails. Velcro traps had 2 parallel strips of velcro fastener, with the hook side facing outwards, stapled to the carpet. Nail traps had 10 30-mm roofing nails pushed from the back of the carpet (McDaniel et al. 2000). Each sample station (hereafter station) consisted of one hair-trap of each type (velcro and nails) nailed to a tree or fallen log at a height of 30 cm and ≤1 m from each other. We never deployed traps directly on the ground. We applied a scent treatment to both traps from each station to trigger a rubbing response from visiting individuals (Reiger 1979, McDaniel et al. 2000). Scent treatments were either 10 mL of catnip oil (*Nepeta cataria*; Minnesota Trapline Products, Pennock, MN) or 5 sprays of a commercial fragrance (Lone Star from Parfums de Coeur [men's cologne imitator of Obsession], Darien, CT) from a pump-spray applicator. In addition, we sprinkled catnip oil traps with dried catnip leaves. We alternated treatments between stations with the initial scent at each transect being selected at random. To minimize the risk of a station being vandalized, we omitted the use of visual attractors (e.g., aluminum pie plates; McDaniel et al. 2000). Instead, at each station we hung, 2 m above the ground, a 2-cm square of green felt to which we added a drop of each of 3 commercial trapping lures intended to appeal to a wide diversity of mammals (Carman's Canine Call, Hawbarker's Wildcat lure No. 1, and Carman's Raccoon Lure No. 1; Minnesota Trapline Products).

We established 4 transects along dirt roads and trails on the eastern side of the ECBR. Transect extents were dependent on road or trail confines so they encompassed 12, 29, 49, and 50 stations, respectively. We set stations 500 m apart with the aid of a handheld Garmin Global Positioning System unit. We deployed 138 hair-trap stations (276 individual hair-traps), and although some (13 stations, 9.4%) were removed or altered by local people, most (125 stations, 90.6%) remained undisturbed. We did not consider altered or removed stations in any analyses. Because more fragrance stations were altered than the ones treated with catnip, the number of active stations differed between aroma treatments (fragrance 59, catnip 66). Transects covered an elevational range of 130 m to 1,717 m, with a straight-line distance of 15.76 km between endpoints (Fig. 1). We left hair-traps in the field an average of 60 days (±10 days) in both the wet and dry seasons from 2001 to 2003 totaling 8,419 trap-days of sampling effort. Total time spent in the field to set up and retrieve the traps was 19 days. We followed the American Society of Mammalogists' guidelines for animal care and use during the course of this study.

From each successful trap, we tallied the total number of collected guard hairs and selected individual hairs that were not damaged to be processed in the laboratory using protocols suggested by Moore et al. (1974). We identified each selected hair to lowest taxonomic level possible (species, genus, or family) with dissecting and optical microscopes by examining external (form, length, color pattern) and internal (diam and medullar pattern) characteristics. We made identifications using the guides of Moore et al. (1974), Arita (1985), and Monroy-Vilchis and Rubio-Rodriguez (2003) and reference museum material. We deposited permanently mounted slides as vouchers at Museo de Zoología, Facultad de Ciencias, Universidad Nacional Autónoma de México.

We used 2 variables to measure trap or station effectiveness: number of recovered guard hairs and number of positive hits (presence). We analyzed number of positive hits (i.e., incidence data, frequency of detection) for both among stations and between trap types. Combination of 2

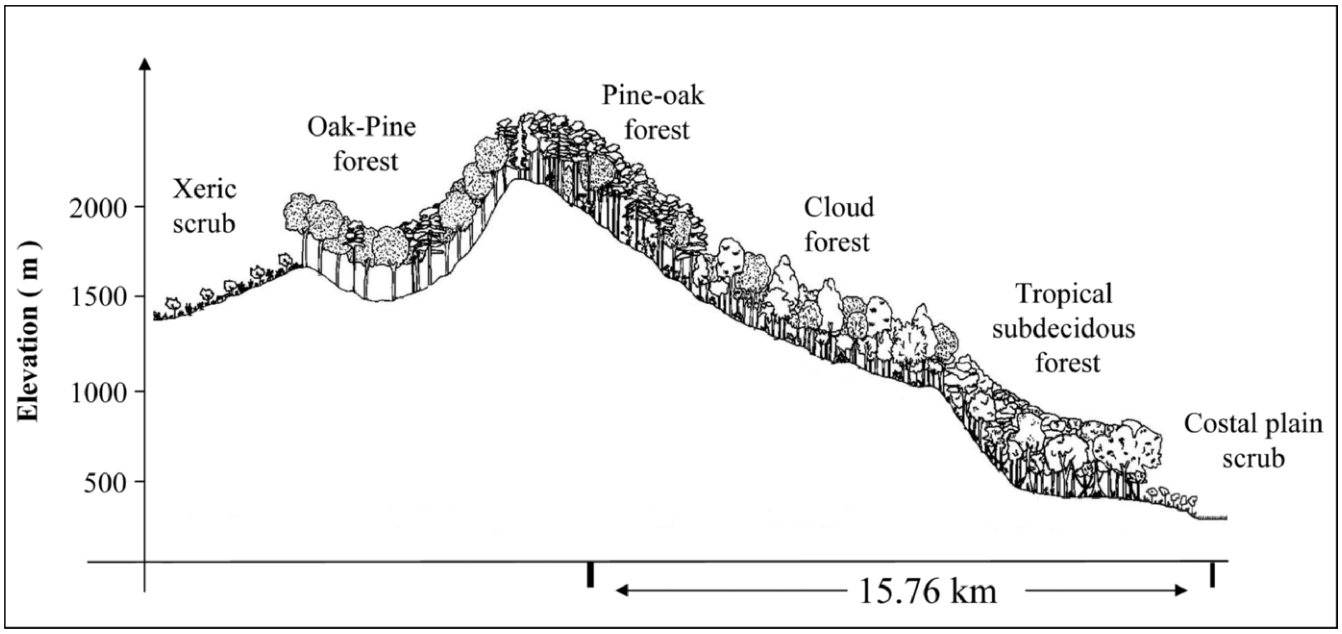

Figure 1. Diagram of the vegetation change along the elevational gradient showing the extent covered by our hair-trap surveys at El Cielo Biosphere Reserve, Mexico (modified after Puig and Bracho 1987).

independent variables, trap type and scent, produced 4 experimental treatments. We used repeated measures analysis of variance to compare mean number of hairs collected in each treatment, with trap type and trap type × scent interaction as within-station factors and scent as the among-stations factor. Because stations were the within subject of analysis, it allowed assessment of interaction between the 4 experimental conditions. Because transects included several habitat types, we included elevation as a covariate to account for possible effects due to vegetation types.

To assess for differences in number of successful stations between scents, we used separate chi-square contingency tests (Sokal and Rohlf 1995) for all data, for each family, and for all species recorded in $\geq$10 stations. We also used chi-square contingency tests to detect differences in success between vegetation types. To identify differences in the number of successful traps between traps with nails and traps with velcro, we used the McNemar's test of correlated proportions (Siegel 1956), which we applied to all data, for fragrance and catnip traps separately, and for each family and species with >10 hair-trap positive hits. For all analyses of incidence data (no. of positive hits) at family level, counts included the tally of individual species from a particular family and the count of visits identified only at family level.

As Downey et al. (2007) suggested that failure to detect felids in hair-trap surveys might be influenced by high densities of gray foxes (*Urocyon cinereoargenteus*) we compared frequencies of concurrent and separate detections between gray foxes and the families Felidae, Procyonidae, and Mephitidae, which had sample sizes large enough for analyses, with chi-square contingency tests. Finally, we did a literature search to compare effectiveness and costs of other carnivore survey methods against hair-trap surveys.

RESULTS

We collected hairs in 48 stations and 64 individual traps out of 125 and 250 stations and individual traps, respectively. Our survey detected 14 mammal species that represent 7 families (Appendix). Average number of species detected in successful traps was 1.4, with a maximum number of 5 species. Because we established transects along existing roads at ECBR, stations were distributed unevenly among vegetation types. Detection frequencies were related strongly to habitat, due to the high number of successful stations at POF compared to other vegetation types (Table 1). On the other hand, frequency of detection did not differ between aroma treatments when we pooled all stations (Table 1) and when we evaluated detection frequencies (mean % of successful stations = 10.4 ± SE 0.72) separately for families Felidae ($\chi^2_1 = 0.04$; $P = 0.83$), Mustelidae ($\chi^2_1 = 1.31$; $P = 0.25$), Procyonidae ($\chi^2_1 = 0.01$; $P = 0.99$), and Mephitidae ($\chi^2_1 = 2.59$; $P = 0.1$) or for gray foxes ($\chi^2_1 = 1.31$; $P = 0.25$), hog-nosed skunks (*Conepatus leuconotus*; $\chi^2_1 = 1.31$; $P = 0.25$), and ringtails (*Bassariscus astutus*; $\chi^2_1 = 0.04$; $P = 0.83$). Instead, trap type had a strong influence on detection frequencies both when we pooled all stations (Table 1) and when we analyzed them by scent treatment separately (Table 2). However, when we considered species and family of trap visitors, trap type became irrelevant for trap success of cougar (*Puma concolor*), Felidae, and Mustelidae hits (Table 2). Overall mammal diversity detected by each scent treatment was almost the same because only ocelots were detected exclusively at fragrance stations (Appendix). In contrast, velcro traps detected only 9 species, whereas nail traps registered all 14 species. A strong association existed between number of collected hairs and number of species detected at any given trap (Pearson $r = 0.6$).

We recovered 3,355 guard hairs from successful traps.

Table 1. Frequencies of detection among habitats, scent treatments, and trap-type treatments for all stations (125) and traps (250) for all medium and large mammals at El Cielo Biosphere Reserve, Mexico, from 2001 to 2003. We conducted habitat and scent analyses among stations with chi-square contingency tables, whereas comparison between trap types evaluated hits between individual traps with correlated proportions (McNemar's test).

Habitat											Scent treatment							Trap-type treatment						
CPV[a]		TSDF[a]		CF[a]		POF[a]					Fragrance		Catnip											
H[a]	NH[a]	H	NH	H	NH	H	NH	χ^2	df	*P*	H	NH	H	NH	χ^2	df	*P*	JF[a]	JH[a]	NO[a]	VO[a]	TS[a]	df	*P*
2	4	17	25	14	15	15	3	21	3	<0.001	27	32	21	45	2.6	1	0.1	77	16	29	3	40	1	<0.001

[a] Abbreviations: CPV, coastal plain vegetation; TSDF, tropical subdeciduous forest; CF, cloud forest; POF, pine–oak forest; H, detection hit; NH, no hit; JF, joint fail; JH, joint hit; NO, nail-trap hit only; VO, velcro-trap hit only; and TS, McNemar test statistic.

Total number of hairs collected with nail traps and velcro traps were different (2,829 and 526, respectively), whereas totals for catnip oil and fragrance were similar (1,776 and 1,579, respectively). A nail trap treated with catnip oil collected the greatest number of hairs (439), whereas the maximum number of recovered hairs in a trap treated with fragrance was 202, also in a nail trap. Elevation was not an important factor as a covariate when we compared mean number of collected hairs between scents and trap types ($F_{1,122} = 0.279$; $P = 0.6$). However, trap type had a strong influence on number of collected hairs ($F_{1,123} = 13.477$; $P < 0.001$) and there was a lack of effect of scent treatment ($F_{1,123} = 0.308$; $P = 0.6$) as well as any interaction between trap type and aroma ($F_{1,123} = 0.153$; $P = 0.7$). Nail traps were more efficient at collecting hairs than were velcro traps with either scent treatment (Fig. 2). We found no evidence for detections being contingent upon presence of gray foxes for both felids (χ^2 with Yates correction; $\chi^2_1 = 0.005$; $P = 0.95$) and procyonids (χ^2 with Yates correction; $\chi^2_1 = 0.25$; $P = 0.62$) but we found a strong association between gray foxes and Mephitidae species ($\chi^2_1 = 9.43$; $P = 0.002$).

DISCUSSION

Our overall detection frequency rate (38%) is similar to that of McDaniel et al. (2000) for hits of all mammal species in their study (45%). We detected 14 species, representing 67% of the medium and large mammal species of this area (Vargas-Contreras and Hernandez-Huerta 2001), and documented ocelots for the first time at ECBR. Additionally, if we exclude species that, due to their habits or morphology are unlikely to be detected with hair-traps (i.e., kinkajou [*Potos flavus*] and nine-banded armadillo [*Dasypus novemcinctus*]), our transects recorded 74% of potential target mammals. The strong relationship between number of collected hairs and number of detected species shows the importance of quantitative evaluation of hair-trap effectiveness. Furthermore, if hairs are desired for genetic analyses the traps should be capable of collecting large numbers of hairs, thus providing a better chance of getting useful samples (Weaver et al. 2005).

Nail traps were superior to velcro traps in several aspects: detection frequencies, total and mean number of collected hairs, and number of recorded species. We chose to test velcro as a hair-collecting surface because of the large difference in hair length between temperate and neotropical mammals. We had concerns that the hair-trap type of Weaver, originally conceived for lynx detection (Turbak 1998), would not be adequate for tropical mammals with shorter hairs. Although velcro was inferior to nails in collecting hairs from trap visitors it might prove useful if used in conjunction with nails. When we separated hairs from both types of traps, we observed that several hairs were actually recovered from the carpet surface, thus a hybrid trap type using both velcro and nails may improve hair collection.

Differences between scent treatments were unsubstantial for detection frequencies, total and mean number of

Table 2. Frequencies of detection between hair-trap type (velcro vs. nails) compared with correlated proportions (McNemar's test) for fragrance-treatment traps, catnip-treatment traps, and for species and families with >10 hits at El Cielo Biosphere Reserve, Mexico, from 2001 to 2003.

Group	Joint fails[a]	Joint hits[a]	Nail only	Velcro only	TS[b]	*P*
Fragrance-treatment traps	32	10	15	2	10.5	0.02
Catnip-treatment traps	45	6	14	1	28.3	0.001
By species						
Gray fox	77	0	10	1	75	0.01
Cougar	77	3	4	0	66.6	0.12
Hog-nosed skunk	77	2	9	0	69.3	0.004
Ringtail	77	5	7	0	61.5	0.02
By family						
Felidae	77	4	8	2	64	0.11
Mustelidae	77	0	8	3	75	0.23
Procyonidae	77	5	11	1	61.5	0.006
Mephitidae	77	4	11	0	64	<0.001

[a] As we used both trap types at each station, joint fails is the no. of times when both traps had no hits and joint hits when both were successful.
[b] df = 1 for all cases. TS = McNemar test statistic.

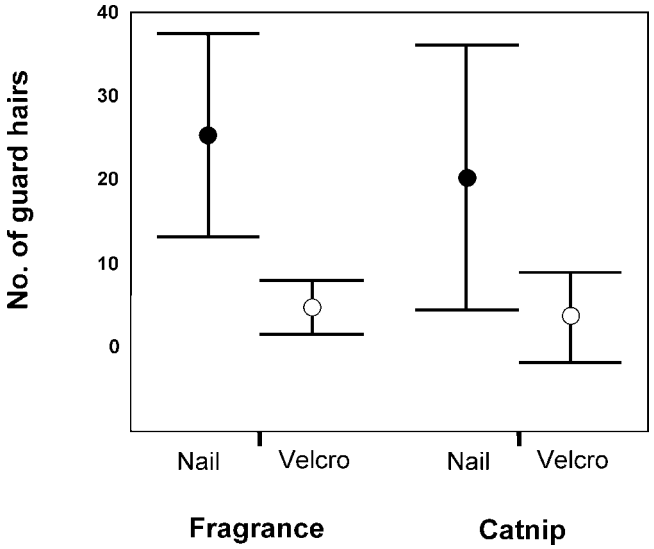

Figure 2. Mean and 95% confidence intervals for number of guard hairs collected in each of the 4 experimental conditions tested at El Cielo Biosphere Reserve, Mexico, from 2001 to 2003. Nail traps are represented by closed symbols (●) and velcro traps correspond to open symbols (○).

collected hairs, and number of recorded species with each scent used in our study. However, scent choice has the potential to affect survey results in other settings (McDaniel et al. 2000, Weaver et al. 2005, Harrison 2006, Schmidt and Kowalczyk 2006) because carnivores exhibit differential responses between scents (Reiger 1979, Mellen 1993). Our study confirms anecdotal information that perfumes and colognes can be inductors of rubbing response and, thus, represent an easily available and viable option for hair-trap surveys (Balme 2005). Both scent and sampling time length are likely strong factors in the survey outcome. Downey et al. (2007) did a hair-trap survey at ECBR that overlapped both geographically and temporally with our study. Nail traps baited with Weaver Cat Call™ used in 8-day sessions yielded 6 species (4 domestic). Although both studies had equal trap numbers, our trapping effort was 4 times greater (1,920 trap-days vs. 8,419 trap-days) because we used longer sampling sessions. Our study shows that longer sampling periods and combined use of scents that appeal to a range of mammals (colognes or perfumes) can aid in detection of species that occur in low densities (e.g., felids). Nevertheless, genetic identifications will require continuous visits for hair collection to prevent DNA degradation (Weaver et al. 2005, Ruell and Crooks 2007).

Hair-traps possess several advantages over other survey methods of secretive mammal species in terms of cost, operation, and return of information (Table 3). Hair-traps offer high reliability, low cost (<$5.00/trap [United States currency]), small size, high portability, weather resistance, and potential for use with a variety of species (Table 3). The success rate from our study (38% for all mammals, 37% for carnivores, and 11% for felids) is comparable to that with scent stations in Costa Rica (35% for all mammals, 19% for carnivores, and 8% for felids; Harrison 1997); however, hair-traps allow identifications that are more accurate and collect additional information (Table 3). The amount of fieldwork (19 days) used to detect 14 mammal species at ECBR represents a small effort when compared to the 100 days of fieldwork that were used to register 17 species at this same zone by means of trapping, sightings, and scat and track identifications (Vargas-Contreras and Hernandez-Huerta 2001). A disadvantage of hair-traps is the amount of time required to obtain identifications if microscopic techniques are used, but this can be reduced with the use of molecular techniques that allow identification of individuals and, thus, provide further details applicable for population studies (Foran et al. 1997, Mills et al. 2000, Beier et al. 2005). Effectiveness of carnivore survey methods appear to be dependent on the context and goals of the study (Wasser et al. 2004, Harrison 2006, Long et al. 2007). Hair-snares detected slightly more species (4) than did scat-finding dogs (3) and camera-traps (3), but scat-finding dogs provided more bobcat samples, which might identify more individuals, in southern New Mexico, USA (Harrison 2006). However, scat-finding dogs and camera-traps were superior at detecting bobcats and fishers in Vermont, USA (Long et al. 2007). Hair-traps and scat-detecting dogs found similar landscape distributions, although scat collection revealed more individuals, in concomitant studies of bears in Alberta, Canada (Wasser et al. 2004). Given these differences, a carefully combined use of techniques might prove the best strategy to optimize data gathering by exploiting advantages of each survey technique. Studies that compare costs and returns for each survey method are needed to maximize restricted financial resources. Cost comparisons between survey methods in temperate zones provide examples for individual species (Choate et al. 2006, Harrison 2006, Long et al. 2007) but no such evaluations exist for mammal surveys in tropical areas. Scat-detecting dogs are more costly than hair-traps (Long et al. 2007) and might have some limitations in tropical areas (Smith et al. 2003, Harrison 2006). Additionally, higher error rates in genotyping fecal DNA, as compared to hair DNA (Pigott and Taylor 2004; but see Ruell and Crooks 2007), indicate the latter as a preferred source for genetic sampling.

Hair-trap surveys can be affected by the differential rubbing response between mammal species (Reiger 1979). A recent study in Ecuador showed that olingos (*Bassaricyon* spp.) visit hair-traps set up in the canopy but no hairs were collected (R. Kays, New York State Museum, personal communication). Successful sampling for these carnivore species will likely necessitate other kinds of scents or trap types such as the ones used for hair collection in primates (Valderrama et al. 1999). Local densities and hunting pressure might also be factors affecting species detection. In our study we failed to detect black bear, jaguar (*Panthera onca*), tayra (*Eira barbara*), collared peccary (*Pecari tajacu*), and brocket deer (*Mazama americana*), each of which likely occur in low numbers at ECBR and also are likely pursued by poachers, thus complicating their detection. Finally, Downey et al. (2007) suggested that failure to detect felids in hair-trap surveys might be influenced by high densities of

Table 3. Comparison of cost (United States currency), limitations, and data provided by common survey methods for detection of large and medium-size mammals.

Feature	Scent stations	Track-plates	Scat-detection dogs	Camera-traps	Hair-traps	
					Microscopic identifications	DNA identification
Cost/unit	<$50 for tools that can be used for multiple stations	$20–40	$300/survey day[a]	$100–800	$5.00	$5.00
Field costs/unit[b]	$0.5–3	<$5		$5–15	$2–4	$2–4
Lab analysis/unit[c]	none or low	none or low	$6–15 for species ID; $40–60 for individuals[d]	$6–15 for film developing	<$10	$6–15 for species ID; $40–60 for individuals[d]
Size and portability	1–2 kg for needed tools	varies, but normally large, heavy, cumbersome		1–2 kg	approx. 40–80 g	approx. 40–80 g
Time between station checks	has to be checked often for optimal results	has to be checked often for optimal results		depends on battery life	can be left for long time	ideally not >2 weeks[e]
Environmental limitations	adversely affected by rainy or moist environs	adversely affected by rainy or moist environs	adversely affected by rainy or moist environs	some are affected by moist environs	none	no, if sample collected quickly
Can species be determined?	yes, but not accurately in all situations	yes, but not accurately in all situations	yes	yes for most cases	yes	yes
Can individuals be detected?[f]	no	mostly no but possible for some species	yes	yes, but not for all species	no	yes, but design needs to be for single sampling
Additional information beyond detection or count data	no	no	diet analysis, physiology information[g,h]	behavior, species other than mammals can be detected	no	yes[h]
Voucher can be registered as	photo or cast	photo or original track surface	original sample, PCR[i] products, gene sequence	photo	hair slide mount	PCR[i] products gene sequence

[a] Harrison (2006).
[b] The cost only considers consumables for the trap itself (scents, trapping lures, batteries, nails, etc.) and does not includes field crew expenses (fuel, salaries, etc.).
[c] Costs include only laboratory consumables and does not consider any equipment, overhead, and personnel costs.
[d] Costs for identification (ID) of individuals assumes that microsatellite polymorphic loci are already known and that 10–15 loci are used for genetic identification analyses (J. Maldonado, National Zoological Park, personal communication).
[e] Weaver et al. (2005).
[f] If individuals can be identified population density, home range, and dispersal estimates can be calculated.
[g] Wasser et al. (2004).
[h] DNA analysis allows the assessment of population density, sex ratio, home range, survival rates, dispersal, paternity, and kinship (Kohn and Wayne 1997).
[i] PCR, polymerase chain reaction.

gray foxes because these might visit and mark hair-traps first, thus rendering the trap unattractive to felids. We found no evidence for felid detections being contingent upon the presence of gray foxes in our data. We suggest that using long sampling periods likely lessens the possibility of any biases that might be induced by early visits of gray foxes to traps.

MANAGEMENT IMPLICATIONS

Nail hair-traps are effective tools to detect presence of neotropical carnivores and can provide enough DNA for genetic studies. Their low operational cost and ease of operation can make them valuable for conservation studies in developing countries with limited funding. We suggest they should be integrated as one of the standard methods in the study of secretive species in tropical areas (Voss and Emmons 1996).

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LITERATURE CITED

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Appendix. Mammal species, and method of detection, recorded at El Cielo Biosphere Reserve, Mexico, 2001–2003, from the hair-trap surveys of our study.

Family	Species	CS[a]	FS[a]	NHT[a]	VHT[a]
Didelphidae	Virginia opossum (*Didelphis virginiana*)	X	X	X	
Canidae	Gray fox	X	X	X	X
Felidae	Margay cat (*Leopardus wiedii*)	X	X	X	
	Ocelot	X	X	X	
	Cougar	X	X	X	X
	Jaguarundi (*Puma yaguarondi*)	X	X	X	X
Mephitidae	Hog-nosed skunk	X	X	X	X
	Hooded skunk (*Mephitis macroura*)	X	X	X	
	Eastern spotted skunk (*Spilogale putorius*)	X	X	X	
Mustelidae	Long-tailed weasel (*Mustela frenata*)	X	X	X	
Procyonidae	Ringtail	X	X	X	X
	White-nosed coati (*Nasua narica*)	X	X	X	X
	Raccoon (*Procyon lotor*)	X	X	X	X
Cervidae	Whitetail deer (*Odocoileus virginianus*)	X	X	X	X

[a] Abbreviations: CS, catnip station; FS, fragrance station; NHT, nail hair-trap, and VHT, velcro hair-trap.