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More Hair than Wit: A Review on Carnivore Related Hair Collecting Methods

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Abstract: Monitoring of presence or estimation of density of carnivores using invasive or disruptive methods, like hunting, life-catching or visual observation can bias research results and might be controversial when studying threatened species. Therefore, non-invasive approaches become increasingly used in the last few decades. Hair collection is one among many useful indirect methods. Knowledge on efficient hair-traps on European carnivore species is limited. Yet, hair-traps have been reported as huge success when tested in enclosures but often are challenging to use in natural environments. Our aim was to compile a comprehensive literature review on hair traps and attractants in order to find out what techniques could be used by field experts. We have found that practical application of some techniques might be hard when studying edge populations but with hair-collection methods additional information can be gathered relatively easily in species core area where animals are abundant. We have also listed some future research perspectives on European carnivore species.

Keywords: hair collection**,** non-invasive methods, carnivores monitoring, baited methods, unbaited methods

Introduction

Carnivore species elusive lifestyle and rarity usually challenge wildlife biologists. Invasive or disruptive methods such as hunting and life-catching can bias research result and harm examined individuals (Long *et al.* 2008). Owing to this, non-invasive approaches become more widespread in the last few decades.

Often large-bodied animals as bears can be surveyed by visual observations (Swenson *et al.* 1994) but these traditional methods had been reported as inaccurate (Solberg *et al.* 2006). Morphology-based track and scat surveys have a long history but uncertainty in species identification has resulted in criticism of natural sign surveys (Heinemeyer *et al.* 2008). Scat collecting could be a good alternative for verifying presence, but to be effective additional molecular approaches are needed. A working dog is usually crucial for collecting scat samples because old samples might have no good quality DNA (MacKay *et al.* 2008). Working dogs are quite expensive due to their training and keeping (Long *et al.* 2007) although sampling is not that labour intensive as it would be without dogs. Animal identification with remote cameras is unambiguous and multiple species can be detected. Moreover, when target species have distinctive marks on the pelage, individual identification can also be carried out (Wegge *et al.* 2004). However, large amount of cameras are necessary for a well-designed survey but risk of theft is often high (Kays & Slauson 2008). Because of this, some researchers refuse to use visual attractants in their surveys (Schmidt & Kowalczyk 2006). Except few species in Europe such as Iberian lynx (*Lynx pardalis*) or genet (*Genetta genetta*), animals usually do not have peculiar marks on their fur.

Hair collection can replace the above mentioned methods both for presence verification and population estimation. Hairs can be collected opportunistically from travel routes, nests, natural rub objects, kill sites or dens. Artificial hair traps like rub pads and posts, snares, corrals, cubbies and modified box traps can also be used to collect samples (Kendal & McKelvey 2008). Hair collecting is preferred mostly

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because construction, installation and maintenance can be very cheap (Long *et al.* 2007). However, additional costs like DNA analysis for individual identification may be still expensive for Eastern European budgets. Fortunately, presence data are known to be relatively easy to collect (Tóth 2008) but fundamental for maintaining unique habitats (e.g. Natura 2000 sites in Europe) or conserving species of Community interest in the European Union.

Rarely, we have knowledge on hair-trap efficiency on European species (e. g. Steyer *et al.* 2013, Anile *et al.* 2010). Yet, hair traps have been reported as huge success when tested in enclosures (Heurich *et al.* 2012) but often become challenging in natural environments (Portella *et al*. 2013, Comer *et al.* 2011, Anile *et al.* 2012).

The aims of this review were to find out (i) which carnivore species were sampled with non-invasive hair traps in the Holarctic ecozone, (ii) which kinds of attractants were used in the studies, (iii) which methods were successful for given species, and (iv) whether these surveys were located in target species core area or in edge populations.

Material and Methods

We have collected information based on publications from Google Scholar (scholar.google.com) and Science Direct (www.sciencedirect.com) published during the period of 2006-2015. Our main interests were the active or baited hair collection techniques.

Species of interest were carnivores occurring throughout the Holarctic ecozone. However, most of the species discussed in this article are from North America and Europe. Most of the Neartic (North-American) carnivore species have similar ecology and behaviour as Palaearctic species (European and north-Asian) species; thus, we have matched similar species to gain larger species groups with similar ecological requirements (Table 1). The purpose of this comparison was to find similarities in species groups and to gather information about the potentially efficient techniques, which were never tested on European species. Non-invasive surveys from tropical environment were excluded from this review due to the environmental and faunistic differences. Our terminology (trap and lure names) is based on Long *et al.* (2008).

Results

Proportion of the articles

Altogether, we found 26 literature sources focusing on species of interest. Some of these surveys dealt with more than one species, thus our initial sample size was higher (n=35). Generally, 14 articles (53.85%) dealt with Palaearctic and 12 (46.15%) with Nearctic species (lynx: 50% and 50%; small felids: 80%: and 20%; canids: 40% and 60%; bears: 60% and 40%; otters: 50% and 50%; badger: 100% and 0%; martens: 42.86% and 57.14%, respectively).

Types of hair collection

Rub stakes or pads were used to sample lynx in almost all cases (n=7, 87.5%). Small felid species were sampled by rub stakes (n=5, 80%) but not rub pads. Two surveys (40%) collected canid hairs from bird nests while gathering overall faunistic data. Canids were also sampled by rub devices (n=2, 40%). All bear studies (n=5, 100%) find natural rub objects as efficient hair collecting surfaces. Enhanced (e.g. barbed wire) rub trees or posts were also often used (n=3, 60%). In case of otters, from the two literature sources one (50%) dealt with modified leg-hold traps and hairs collected from bird nests (50%). Badger hairs were found in bird nests (n=2, 66.66%); travel route snares at den entrance was also used in one case (33.33%). Martens were sampled unsuccessfully by rub pads (n=1, 12.5%) while cubbies and box traps were used successfully (n=5, 62.5%), (Table 2).

From the 41 occasions, modified leg-hold traps occurred only in one survey on one species (otter, n=1, 2.44%). Bear collars gave the same result. Rub devices were often used (n=15, 36.59%), as well as bird nests (n=9, 21.95%). From the seven species groups only bears were not sampled by bird nest analysis (Table 2).

Hair collection: lures

Most surveys (n=23, 60.53%) used active methods, which require baits or lures to collect samples. Out of 26 surveys, seven (23.08%) mentioned more than one lure or bait. Liquid attractants were used in 19 (40.43%), whereas food baits were mentioned in seven (14.89%) from a total of 47 samples.

Lynx and small felids were almost exclusively sampled by using attractants (n=7, 87.5%, n=4, 80%, respectively). Most common lynx attractant were beaver castoreum and catnip (n=6, 75%). Valerian was used more often to attract small felids (n=4, 80%), followed by catnip (n=1, 20%). Canids were also sampled by baited techniques (n=3, 60%), and commercial scent lures were often used (n=2, 40%). Bears were readily sampled by unbaited methods (n=4, 80%). In one case, a commercial scent was applied to attract otters (n=1, 50%). Badgers were always sampled by passive (unbaited) methods (n=3, 100%). Most marten surveys were based on baits (n=6, 75%). They were attracted either with com-

Table 1. Carnivores considered as similar or vicariant species and compiled in one category

North America		Europe		Category in the manuscript
Name	***Scientific name***	**Name**	***Scientific name***	
Canadian lynx	*Lynx canadensis*			Lynx
Bobcat	*Lynx rufus*			
		Eurasian lynx	*Lynx lynx*	
Brown bear	*Ursus arctos*	Brown bear	*Ursus arctos*	Bears
Grizzly bear	*Ursus arctos horribilis*			
Dog	*Canis lupus familiaris*	Dog	*Canis lupus familiaris*	Canids
Grey wolf	*Canis lupus*	Grey wolf	*Canis lupus*	
Coyote	*Canis latrans*			
		Golden jackal	*Canis aureus*	
Wildcat		Wildcat	*Felis silvestris*	Small felids
Domestic cat	*Felis catus*	Domestic cat	*Felis catus*	
North American river otter	*Lutra canadensis*			Otters
		Eurasian otter	*Lutra lutra*	
		Eurasian badger	*Meles meles*	Badger
Fisher	*Pekania pennanti*			Martens
American marten	*Martes americana*			
		Stone marten	*Martes foina*	
		Pine marten	*Martes martes*	

mercial scent lures (n=3, 42.86%) or food baits (n=4, 57.14%; Table 3).

Core area and edge populations

Most surveys were carried out where animals were already known to occur in greater abundance (core area, n=32, 84.21%). In area edge populations, where observations were scarce, non-invasive hair collection surveys were rarely published (edge, n=3, 7.89%). In addition, some of the articles described tests in enclosures (n=3, 7.89%; Table 4).

Discussion

Our aim with this review is to present several hair-collection techniques on European carnivore species. There have been no comparable reviews on hair sampling since 2008 (Long *et al.* 2008). In the recent years, only few hair collection surveys (n=14) have been carried out in Europe. Therefore, we treat Palaearctic and Neartic species as similar ones and categorised them in groups (Table 1). With this compilation, we have found few similarities based on attractants and collection methods.

Lynx and small felids use their urine and cheek rubbing behaviour to mark their territories (MacDonald & Loveridge 2010). Although these signs are known to be locally constant, unbaited survey methods are rare among lynx hair-trapping techniques. Schmidt & Kowalczyk (2012) have used Eurasian lynx (*Lynx lynx*) signs to find sample sites but their monitoring was based on scented rub pads. Rub pads or stakes are sometimes used without scents when testing is the main interest (Heurich *et al.* 2012). When scent-free hair-traps are used as controls, the sample size is usually smaller when applying unbaited devices (Hanke & Dickman 2013). Rub devices were the only baited sample collectors in recent studies on felid detection (n=11, Table 2.). The first rub pad study found that catnip with beaver castoreum works better on lynx than other tested attractants (McDaniel *et al.*2000). Since then, several studies (n=6, Table 3) used castoreum and catnip oil (or imitation) for attracting felids. Schmidt & Kowalcyk (2006), Davoli *et al.* (2013) Long *et al.* (2007), and Heurich (2012) successfully use this scent in enclosures. However, Matthew (2012) and Comer *et al.* (2011) obtain unsatisfactory results for Canada lynx (*Lynx canadensis*) and bobcat (*Lynx rufus*). It should be noted that Comer *et al.* (2011) used fairly low amount of scent (two drops of catnip in 4 ml glycerine). Catnip also seems to be less attractive for feral cats (*Felis catus*) in Hungary (Patkó *et al.* 2015). The second most used scent lure on felid species is valerian (n=4, Table 3), which can be as controversial as catnip. Based on recent studies, valerian is only used on small felid species, such as wildcat and feral cat. Kéry *et al.* (2010) and Steyer

Table 2. Different devices used to carry out non-invasive hair collection surveys

	Rub pad	Rub stake	Hair corral	Rub tree, post trap	**Travel route snare**	**Cubbies and box traps**	**Modified leg-holds and snares**	**Natu-ral rub objects**	**Nest**	**Literature**
Lynx		+								Schmidt & Kowalczyk 2006
	+									Long *et al.* 2007
		+								Ruell & Crooks 2007
									+	Tóth 2008
		+								Comer *et al.* 2011
		+								Heaurich *et al.* 2012
	+									*Matthew 2012
	+									Davoli *et al.* 2013
Small felids									+	Tóth 2008
		+								#Anile *et al.* 2012
		+								Hanke & Dickman 2013
		+								Steyer *et al.* 2013
		+								Kéry *et al.* 2010
Canids									+	Patkó *et al.* 2014
		+								Ruell & Crooks 2007
									+	Tóth 2008
	+									Ausband *et al.* 2011
	+									*Matthew 2012
Bears								+		Pérez *et al.* 2009
								+		Karamanlidis *et al.* 2010
				+				+		Stetz *et al.* 2010
			+	+				+		Sawaya *et al.* 2012
				+	+			+		Frosch *et al.* 2014
Otters							+			Depue & Ben-David 2007
									+	Patkó *et al.* 2014
Badger									+	Tóth 2008
					+					Balestrieri *et al.* 2010
									+	Ondrušová & Adamík 2013
Martens						+				Pauli *et al.* 2008
									+	Tóth 2008
						+				Williams *et al.* 2009
						+				Mullins *et al.* 2010
									+	Ondrušová & Adamík 2013
						+				Zielinski *et al.* 2013
						+				Olson *et al.* 2014
	+									#Long *et al.* 2007

*=extremely low detection rates
#=failed to produce hair samples

et al. (2013) could collect enough samples from wildcats for genotyping individuals. On the other hand, cats from Sicily, while passing by valerian soaked rub stakes, refused to rub (Anile *et al.* 2012). Interestingly, food sources (tuna oil, see Hanke & Dickman 2013) have not been used (n=1, Table 3) for sampling felid species.

Canids are rarely sampled by direct hair collection surveys but can often be detected as by-catches (Kendal & McKelvey 2008). Since 2006, canid species have been sampled by rub pads or stakes (n=3, Table 2). In successful studies, commercial scent lures were used (Ruell & Crooks 2007, Ausband *et al.* 2011). Matthew (2012) used 1-2 ml of ca-

Table 3. Different baits and scents used to carry our non-invasive hair collection surveys

	Beaver castoreum	Catnip oil	Dried catnip	Beaver castoreum + catnip oil	Beaver castoreum + imitation of catnip oil	Valerian	Commercial scent lure	Canid glands	Cat urine	Tuna oil	Meat scrap	Marmalade	Aged cattle blood, decomposed fish, anise	No bait or scent	Literature
Lynx					+										Schmidt & Kowalczyk 2006
			+				+								Long *et al.* 2007
							+								Ruell & Crooks 2007
														+	Tóth 2008
				+											Heaurich *et al.* 2012
	+	+	+												Matthew 2012
		+	+												Comer *et al.* 2011
				+											Davoli *et al.* 2013
Small felids						+									Anile *et al.* 2012
														+	Tóth 2008
						+									Steyer *et al.* 2013
						+									Kéry *et al.* 2010
		+	+			+			+	+					Hanke & Dickman 2013
Canids	+							+							Matthew 2012
							+								Ruell & Crooks 2007
														+	Tóth 2008
							+								Ausband *et al.* 2011
														+	Patkó *et al.* 2014
Bears														+	Pérez *et al.* 2009
														+	Karamanlidis *et al.* 2010
														+	Stetz *et al.* 2010
													+		Sawaya *et al.* 2012
														+	Frosch *et al.* 2014
Otters							+							+	Depue & Ben-David 2007
														+	Patkó *et al.* 2014
Badger														+	Tóth 2008
														+	Balestrieri *et al.* 2010
														+	Ondrušová & Adamík 2013
Martens			+				+								Long *et al.* 2007
														+	Ondrušová & Adamík 2013
							+				+				Zielinski *et al.* 2013
											+				Pauli *et al.* 2008
														+	Tóth 2008
											+				Williams *et al.* 2009
							+				+	+			Mullins *et al.* 2010

Table 4. Survey relations to study areas

	Core	Edge	Enclosure	Literature
Lynx	+			Schmidt & Kowalczyk 2006
	+			Long *et al.* 2007
	+			Ruell & Crooks 2007
		+		Tóth 2008
	+			Comer *et al.* 2011
			+	Heaurich *et al.* 2012
	+			Matthew 2012
	+			Davoli *et al.* 2013
Small felids	+			Tóth 2008
	+			Anile *et al.* 2012
	+			Hanke & Dickman 2013
	+			Steyer *et al.* 2013
	+			Kéry *et al.* 2010
Canids	+			*Patkó *et al.* 2014
	+			Ruell & Crooks 2007
	+			*Tóth 2008
	+			Ausband *et al.* 2011
	+			Matthew 2012
Bears	+			Pérez *et al.* 2009
	+			Karamanlidis et al. 2010
	+			Stetz *et al.* 2010
	+			Sawaya *et al.* 2012
	+			Frosch *et al.* 2014
Otters	+		+	Depue & Ben-David 2007
		+		Patkó *et al.* 2014
Badger	+			Tóth 2008
	+			Balestrieri *et al.* 2010
	+			Ondrušová & Adamík 2013
Martens	+		+	Pauli *et al.* 2008
	+			Tóth 2008
	+			Williams *et al.* 2009
	+			Mullins *et al.* 2010
	+			Ondrušová & Adamík 2013
		+		Zielinski *et al.* 2013
	+			Olson *et al.* 2014
	+			Long *et al.* 2007

*=Only wolf (*Canis lupus*) has an edge population in the area. → It seems to me that the sentence has different character sizes.

nid glands to detect grey fox (*Urocyon cinereoargenteus*), coyote (*Canis latrans*) and bobcat but the study that lasted for 3500 trap nights resulted in seven hair samples, with average sample size 1.7 hairs/hit, which can be considered as highly unsuccessful. Kendal & McKelvey (2008) mentioned a few earlier studies where wolves were sampled by wire strung across underpasses (Clevenger *et al.* 2005), or detected by hair corrals originally installed for bears (Poole *et al.* 2001). Tree or post traps can also sample canids as by-catches.

Recent studies on bears have idnot used any lures (n=4, Table 3) but, if hair corrals are used for collecting samples, a special bait of aged cattle blood, decomposed fish, or anise can be used (Sawaya *et al.* 2012). Rub trees wrapped in barbed wire can enhance sample size when studying bears, although it needs knowledge of the studied area and fairly high bear abundance. However, with or without baits, non-invasive sample collection usually has a favourable result for bears.

Otter presence can be verified easily through their marking behaviour, slides, scats and tracks (Lanszki *et al.* 2008) but hair or scat samples are needed for individual identification. Modified leg-hold traps or snares (Depue & Ben-David 2007) can be installed on their tracks to collect samples.

In case of small martens, food baits are used more often than scents. Cubbies and modified box traps were applied almost exclusively (n=5, Table 2) to monitor marten species. Long *et al.* (2007) tested different non-invasive methods (scat detection dogs, camera traps and hair snares) to detect few carnivore species, like fisher (*Pekania pennanti*). Due to the specific hair collecting method (rub pad), fishers could not be detected. Other hair snare mechanisms designed for martens (e.g. cubbies) might have increased detection rates (Long *et al.* 2007).

Only one unbaited method, the bird nest analysis, was efficient enough to validate the occurrence of every species group except bears (n=6, Table 2.). Tóth (2008) could detect Eurasian lynx and small felids based on hairs morphological features collected from bird nests. Canid hairs often can be found in nests (Tóth 2008, Patkó *et al.* 2014) but these originate from domestic dogs or red fox (*Vulpes vulpes*). Otter, badger and marten hairs were detected from bird nests as well (Patkó *et al.* 2014, Ondrušová & Adamík 2013, Tóth 2008). However, bird nest analysis usually gathers faunistic and not individual specific data. Eurasian badger (*Meles meles*) was also sampled successfully by another unbaited method (travel route, barbed wire at den entrance, Balestrieri *et al.* 2010).

Although, these devices usually are quite cheap (1-5 euro/rub stake, Heurich *et al.* 2012), additional costs like field-work, lab and transport can increase the overall cost of a survey. Still, comparing all expenditures of detection dogs and remote cameras, hair

Table 5. Already tested techniques and future research perspectives on hair collecting surveys

	Successfully and/or often used		Suggestion for future research perspectives on	
	methods	attractants	methods	attractants
Lynx	Rub devices, bird nests	Catnip, beaver castoreum	Travel route wires	Valerian, natural scents, urine
Small felids	Rub devices, bird nests	Valerian	Large cubbies, modified box traps	Catnip, natural scents, urine
Bears	Rub tree, hair corral	Special lure mixture, or unbaited	-	-
Canids	-	-	Travel route wires, bird nests	Food baits
Otters	-	-	Travel route trap, snares	Food baits, or unbaited
Badger	Bird nests	Unbaited	Travel route wires	Food baits
Martens	Cubbies, modified boxtraps	Food baits	-	Commercial lures

collection method can be a viable tool for researchers working with limited resources. The total cost of using detection dogs can rise up to 20,000 dollars, while remote cameras can cost about 16,000 dollars. Unfortunately, sometimes the cheapest methods like hair snares (9000 dollars) can lead to the lowest sample size (Long *et al.* 2007).

Practical aspects of studies can directly influence field and lab costs, thus more details should be given in description of different techniques. Sometimes hair sample size is not well defined in the surveys. In our experience, sample corresponds to data that are sufficient for answering our question (e. g. species or individual identification). We believe that sample size that is not well defined can lead to false assessment of a method. For example, if we want to carry out a faunistic survey without individual identification, we only need a few hairs to identify species (Patkó *et al.* 2014). In this case, if we have one or two hairs from species like bears or badgers, which are easy to identify based on their hair morphology (Patkó *et al. in press*) we can meet the requirements of a faunistic study. However, such sample size, which in this case is one hair, could be misleading. Defining how many hairs were collected in one sample can be essential.

Many hair-collecting surveys were carried out where examined species presence was known to be constant in their core area (Table 4). In these areas cheap hair-collection methods can provide valuable additional information on population genetics (Mullins *et al.* 2010), abundance (Frosch *et al.* 2014) and movement (Davoli *et al.* 2013). In some cases species tracks and signs come to aid the monitoring, therefore hair-snaring devices enhance some already available data (Schmidt & Kowalczyk 2006). In other cases trap and attractant testing in enclosures result in large amount of collected hairs (Heurich *et al.* 2012). Nevertheless, sometimes when these methods are applied in the field, where surveyed species are rare (e.g. edge populations) results are questionable (Anile *et al.* 2012, Matthew 2012). Successful studies are easier to publish, thus pitfalls that might give insights on practical application remain hidden. Finding a way for publishing negative results would be essential for future research perspectives.

The utility of hair samples is linked to pilot studies and survey design, which is linked directly to target species behaviour and biology (Kendal & MacKelvey 2008). We could argue that the efficiency of a survey also depends on the rarity of the targeted species. Probably there are studies focusing on area edge populations (Table 4), where rare and elusive carnivore observations are scarce and their density is lower. We hypothesise that these studies might be well prepared and carried out but due to sample rarity they remain unpublished. In the case of area edge populations regular and efficient monitoring is extremely hard to be carried out. Presence data might be collected only irregularly based on typical signs of certain species (e.g. bear faeces, golden jackal voice, lynx urine spray, opportunistic hair collection) or remote cameras.

While non-invasive and non-disruptive eDNA techniques are developing rapidly (Lefort *et al. unpublished data.*), we sometimes still cannot overcome challenges of practical implementation of such studies. In Europe, plenty of methods and attractants studies on certain carnivore species remain unpublished (Table 5). In technical surveys with multiple variables, such as hair sampling, researchers should consider publishing basic data related to hair collection. We recommend compiling a data table in the journals appendix. Tables should focus on trap nights, hit/trap, refreshing periods, type of attractants, target species, by-catches, sample size and extent of study area. It seems that successful hair collecting studies depend not only on the researchers' expertise and monitoring method, but also on the rarity of the species.

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