Using Scent-Matching Dogs to Identify Individual Amur Tigers from Scats

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ABSTRACT Scent-matching dogs have previously been used to identify caged individual Amur tigers (*Panthera tigris altaica*) by fecal material (scat), but this technique has not been tested in the wild. We tested the hypothesis that trained dogs can identify individual tigers by unique characteristics present in scat. To conduct this work, we used 5 dogs and 58 scats from 25 known individual tigers in independent trials. Dogs correctly selected matched test scats at an average rate of 87% (SE ± 1.4%, $n = 521$ trials). The average accuracy rates for 4 dogs increased to 98% (SE ± 1.6%, $n = 86$ sets of repeated-trials) using repeated-trial tests. Each of 5 dogs made correct choices better than expected by chance (dog 1 $\chi^2_1 = 507.9$, $P \leq 0.001$; dog 2 $\chi^2_1 = 882.1$, $P \leq 0.001$; dog 3 $\chi^2_1 = 374.1$, $P \leq 0.001$; dog 4 $\chi^2_1 = 379.2$, $P \leq 0.001$; and dog 5 $\chi^2_1 = 103.9$, $P \leq 0.001$). Four dogs were able to match 11 scats deposited over a 4-year period from one tiger with an accuracy of 100% ($n = 40$ trails). This method may be a useful alternative to genetic analyses that are used in conjunction with scat-sampling schemes in studies for which DNA genotyping is impractical or ineffective. Used with mark–recapture surveys to estimate species abundance, scent-matching dogs have the potential of being important tools in the study of wild Amur tigers, as well as other wildlife species. (JOURNAL OF WILDLIFE MANAGEMENT 71(4):1349–1356; 2007)

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Accurate survey methods are necessary to monitor the status and dynamics of endangered populations of large carnivores such as the Amur, or Siberian tiger (*Panthera tigris altaica*). Like many other large carnivores, tigers are notoriously hard to monitor because they are secretive, occur at low densities, range widely, and are very rarely observed. Techniques used to identify individuals during population monitoring include track size measurements (Sharma et al. 2005), camera-traps (Karanth and Nichols 2002), and genetic analysis of DNA extracted from hair or scat (Mills et al. 2000, Taberlet et al. 2001). These methods, however, can vary in their reliability depending on the species or subspecies being studied and the habitat where they are used. Thus, there is a need for additional and varied methods for identifying individuals to give biologists more flexibility when designing field studies.

The traditional method for monitoring Amur tiger populations in the Russian Far East is to use track surveys in snow for total counts or indices of abundance. Surveys of tigers have relied on expert assessments that derive what is likely a conservative estimate of Amur tigers based on grouping tracks of similar size (determined from pad width, which can reliably differentiate some sex and age classes [Kerley et al. 2005]), and the likelihood that tracks of similar size at varying distance from each other represent a single individual, based on known home-range estimates (Goodrich et al. 2005) and daily travel distances (Kaplanov 1948, Matyushkin et al. 1996, Smirnov and Miquelle 1999). Although the power of track counts in snow to identify changes in relative abundance has been addressed (Hayward et al. 2002), the relationship between track abundance, or expert assessments, and actual tiger abundance has not been determined. Alternatively, mark–recapture approaches that employ either camera-traps, or genetic analysis of DNA extracted from hair or scat to identify individuals have been used for a number of carnivores (Mills et al. 2000, Taberlet et al. 2001, Karanth and Nichols 2002). Whereas camera-trapping has proved effective for some tiger populations, DNA analyses have so far not proven effective in identifying individuals due to low genetic variability in the Amur tiger population (Luo et al. 2004, Russello et al. 2004). Additionally, the effectiveness of camera-trapping is reduced in low-density populations, such as the Amur tiger, requiring long sampling periods (Karanth and Nichols 2002). Camera-traps also often malfunction in cold temperatures, even though winter may be the best time for surveying some large carnivores in northern environments (A. B. Kostyria, Wildlife Conservation Society [Russia], personal communication). In contrast, if individuals could be identified from scat by means other than DNA, then survey routes could be more flexible in summer and animals could be tracked through the snow to a scat in winter, perhaps resulting in shorter and more efficient sampling periods.

Over the past decade, dogs have been increasingly used in wildlife studies to search and identify scat by species. This application arose from the knowledge that dogs have long been used in law enforcement to find lost or buried people, locate illegal substances such as narcotic or explosives, and identify criminal suspects. In Russia, dogs have been trained to identify individual Amur tigers (Sokolov et al. 1990, Salkina and Solomkina 1997, Krutova 2001), as well as other vertebrate species including brown bears, mice, and frogs (Sokolov et al. 1990), from scent with a reportedly high degree of success. The approach has not been tested, however, in a statistically rigorous manner for use in field studies. If dogs can reliably identify individual tigers (or other species) from scat, then they could be used as an alterative to DNA analyses for doing mark–recapture studies for projects where the collection, processing, storage, and

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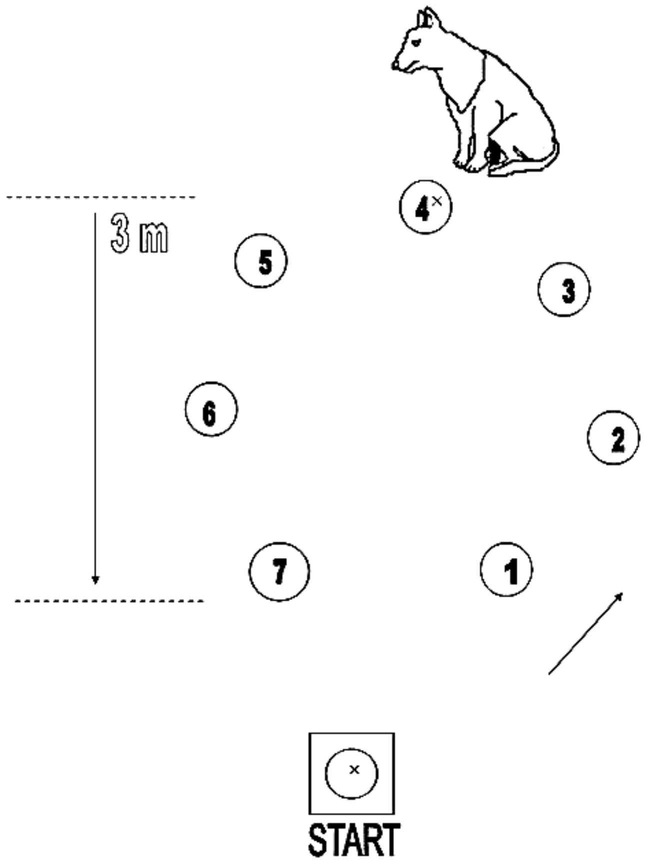

Figure 1. Trail design and scent lineup used in our accuracy trials conducted between December 2002 and March 2005 near the Lazovsky State Nature Zapovednik in the Russian Far East. We modeled trials after Krutova (2001) with some modifications. Each circle represents a jar with a scat in it and the circles marked with an "x" represent scats from the same tiger. The scat in the start position is the test scat, which is the "unknown" to be matched from the lineup.

shipment of samples to a genetic laboratory may not be a feasible or affordable option. The goal of this study was to assess the accuracy of dogs at identifying individual tigers from scats, and the potential application of this ability for mark–recapture studies. We tested the hypothesis that trained dogs have the capacity to identify individual Amur tigers by unique characteristics present in their scat.

STUDY AREA

We housed, trained, and tested 5 dogs in a 0.35-ha area adjacent to the Lazovsky State Nature Zapovednik in the Russian Far East. We housed dogs in separate outdoor pens (5 × 3 m) with covered shelters and we exercised each dog within a larger fenced area for 2–3 hours twice per day. We conducted scent trials indoors in a 5 × 5-m building to control for ambient scents and avoid potential distractions for the dogs.

METHODS

Dogs and Dog Training

We trained our dogs using some techniques similar to Schoon and Haak (2002), but we used a circular trial design and rewarded dogs with food (Sokolov et al. 1990, Krutova 2001). We trained 5 dogs: one male German shepherd mix (dog 1), one female German shepherd (dog 2), one female Labrador retriever and Lieka cross (dog 3), one female German wire-haired pointer (dog 4), and one female Labrador retriever and Russian spaniel cross (dog 5). From December 2002 to March 2005 we conducted controlled experiments that tested each dog's ability to correctly identify individual tigers by scent in scat (see below). We raised our dogs from 6-week to 8-week-old pups and selected them based on a combination of play and food drives of the pups and their parents. Both play and food drives of dogs are used as typical motivators in detection-dog disciplines (Schoon and Haak 2002, Smith et al. 2003, Wasser et al. 2004). We began training pups at 4–6 months of age. The Lazovsky State Nature Zapovednik's science and ethics committee reviewed and approved the protocols used to conduct this research in accordance with regulations that govern Russian Zapovedniks.

Training.—We trained dogs to perform a trial design patterned after Sokolov et al. (1990) and Krutova (2001) to test the overall effectiveness of the method. Dogs made identifications by matching a base sample (the test sample) to a scat of the same tiger in a scent lineup, which was represented as a selection of 7 scat jars (with scent boxes) set in a semi-circle, each spaced ≥50 cm from one another (Fig. 1). Upon entering the room with the handler, we trained each dog to go immediately to the test sample located at the start position (Fig. 1) and smell the contents of the test jar for a period of 1–5 seconds. The dog then moved around the floor, smelling each of 7 more jars consecutively, all randomly selected from the scat collection except those selected to match the test sample (test match). Each dog worked on a leash, in front of the handler, and was allowed to sniff all of the jars before making a decision. The dog selected a jar by sitting next to it, thereby identifying the scat as matching the test sample.

We began training young dogs to smell jars, follow a trail of jars, and smell each one consecutively, using 15–20 jars filled to the top with wadded paper each with a small piece of hot dog (≤1 × 1 cm) placed on top and jars set about 20 cm apart in a circle on the floor. We brought dogs, fitted with harness and leash, into the room with jars, took them to the first jar and gave the command "smell" while the dog ate the hot dog. After that we let the dog find the hot dogs by following the trail of jars. Most dogs quickly and enthusiastically learned (after approx. 3 d) to work in front of the handler and to explore each jar for its contents. At that point, we stopped placing hot dogs in every jar, placed the jars farther apart, and covered them with the scent boxes.

We next taught the dogs to sit at the appropriate jar in the scent lineup. To accomplish this, we emptied all jars except the test jar and one match that contained scats from the same tiger. On top of each scat jar, we placed a small screen cup made of a tea strainer, and on those cups we placed 3–4 pieces of hot dog. The cups allowed the dog to eat and smell the jar's contents without disturbing the scat. We set the test jar apart from the others by placing it on a raised platform (a 15-cm-high stool) and we brought the dog into the room, and gave the command to "smell" at the test jar. From earlier training, the dog began smelling each jar consecutively and when the dog stopped to eat the hot dogs at the matching jar (where scat from the same tiger was placed) we gave the command to sit followed by praise and more treats from the handler's hand. In this way the dogs learned to anticipate a treat from the handler after sitting at the matching jar. We repeated this exercise for several days, each time changing the position of the matching jar in the lineup and frequently changing the identity of the tiger scent to be matched, until the dog began sitting at the match without being issued a sit command. At that point we introduced the dogs to a more complicated trial design that had scats from different tigers in every jar in the lineup where one was a match. We also gradually stopped using hot dogs on the jars and gave only treats from our hands after the dog sat at the correct match. When the dog chose the correct jar >70% of the time without our help we introduced the dog to more matching jars in the lineup so the dog could expect to sit at 1, 2, or 3 matches in every trial and we varied the reward type between praise and food, and praise alone. We completed the training in 2–4 months, and performance usually improved over the next 4–6 weeks with practice. When we felt that a dog was working to the best of their ability we began using it in accuracy trials.

Because even the best dogs vary in their daily performance, we monitored dogs for their motivation for work by proceeding each trial with a practice run in which the dog was led through the test procedure to identify a different set of matched scats. On the rare occasions when a dog was unmotivated to work, we stopped work with that dog, put them in their kennel, and tested them again on the following day. We stopped using dogs that were unmotivated >10% of the time. We worked dogs once per day and 3–5 days per week. Each trial took 10–15 minutes to do and a dog performed 3–7 trials per day. The total number of trials performed by each dog varied due to differences in age, training, and experience of dogs.

Scat Collection and Preparation

We obtained scats of known individual tigers from a variety of sources including known tigers in zoos, circuses, and from wild Amur tigers in the Russian Far East. We collected scats only when an individual could be positively associated with each scat. We collected scats from captive animals ≥24 hours apart and from individual tigers that were housed separately in Russian circuses and zoos. We collected single and multiple samples of scats from wild tigers (some radiocollared) by following a single set of tracks and collecting scat only associated with those tracks and at capture sites of radiocollared animals (Goodrich et al. 2001). For wild individuals that were not radiocollared we collected scats during snow-tracking in geographically distinct areas (i.e., 2 times farther apart than the $\bar{x}$ diam of home ranges of Amur tigers; Goodrich et al. 2005) or by following tracks of different-sexed individuals based on track size (Nikolaev and Yudin 1993, Kerley et al. 2005) in the same area, to avoid the possibility of following tracks of the same tiger twice. While tigers in circuses and zoos were generally retained on a constant diet (which may aid dogs in identifying individuals), the diet of wild tigers was varied, consisting of red deer (*Cervus elaphus*), wild boar (*Sus scrofa*), and sika deer (*Cervus nippon*), as well as a host of other species (Miquelle et al. 1996). We collected scats of both males and females of varying ages, thus best mimicking the composition of scats that might be collected from a wild population.

Any scats of interest can be collected from the wild and used for identification purposes; however, once a scat has been collected, care must be taken to keep it from growing mold, which can interfere with a dog's ability to detect individual scent (Krutova 2001). To that end, we wrapped freshly collected scats in aluminum foil, inserted them into 2 zip-lock bags to avoid contamination of scent from other scats, labeled them, and kept them cool until they could be frozen. For trials, we placed a small piece of scat (approx. 5 mm × 1 cm in length) from each sample in a separate 0.5-L glass jar (labeled for identification), closed with a tight-fitting lid, and kept frozen until we used it in trials. We washed all jars with soap, rinsed, and boiled them for 10 minutes before being used. We removed lids during trials.

To ensure that dogs were identifying the scent of individual tigers and not just individual scats, whenever possible we used ≥2 different scats from the same tiger during trials, one as the test scat and another from the same tiger amongst a set of randomly selected scats from the reference collection of scats for the scent lineup. However, for 10 tigers we had only one scat, which we divided into 2 jars.

During trials, variation in scent strength between jars may affect dog behavior and increase error rate (i.e., relatively strong scent can attract or repel a dog; Krutova 2001, Schoon and Haak 2002). To provide dogs with approximately the same scent strength from each sample, we made 2 adjustments in presentation. First, we left newly made scat jars open and outside for 48 hours before use so that scats could dry and air out. Second, we covered each scent jar by a scent box, created by placing plastic buckets (16 cm tall and 17 cm diam) upsidedown over each jar with a 9-cm hole in the top so that the dog could not see the jar but had to put its nose over or into the hole to smell the contents. This allowed the dog to better pinpoint the scent of each scat in a room with many scats (Hurt et al. 2000).

Not all scats were appropriate for dog identifications because dogs may be attracted to some scents, which could cause the dog to return to that scat in the scent lineup repeatedly, regardless of the test scat, and resulting in misidentifications (Krutova 2001, Schoon and Haak 2002). To filter out inappropriate scats, we observed dogs' behavior during practice trials and if the dogs continually returned to a jar in the scent lineup regardless of the test scat (i.e., became fixated on that scat), we discontinued using that scat in further trials.

Trial Design

Test design.—We conducted randomized, independent accuracy trials to test the accuracy of dogs at identifying individual tigers from scat. For trials to be truly independent it would be necessary to use scats from different tigers for every trial to ensure that dogs were not learning to recognize a tiger by repeated use of one set of scats. Access to such a large number of tigers and scats was not possible, however, potentially violating the assumption of independence. To minimize this problem, we randomly selected combinations of 6 scats, as well as the matching scat, for each trial from our total sample (with replacement) to ensure as much independence as possible. Although conditions may have violated the assumption of independence of scat samples, our sample size (of scats and tigers) and approach probably would closely mimic testing conditions for a population of size similar to that used in existing mark–recapture protocols for tigers (Karanth and Nichols 2002).

Two people ran the trials. One person handled the dog (handler) and the other person (assistant) set out the scat jars for each trial. The assistant worked independently so that neither the handler nor the dog knew the position of scats within the scent lineup, thus avoiding the handler unintentionally influencing a dog's choice. In every test, there was either 1 jar or 2 jars in the scent lineup that contained scat from the same animal as in the test jar. We used single-choice test trials to test how accurately dogs could identify tigers from scats and we compared results to those from double-choice tests to determine whether accuracy rates were affected by our trial design (i.e., when dogs needed to choose 2 scat to be correct).

Single-choice tests.—In single-choice tests we placed one jar with scat from the same tiger as contained in the test jar in a scent lineup with 6 randomly selected scat jars. If the dog sat in front of the correct choice, we considered it a correct identification. We considered selection of the wrong jar a failure and we recorded what mistake the dog made.

Repeated and cross-tests.—We used the results of single-choice trials to determine if repeated tests (1 dog) or cross-tests (3 dogs) improved accuracy rates of identifications compared to the percentage of correct choices made in total trials. For repeated testing, we calculated the proportion of tigers that were correctly identified by a dog in $\geq$2 out of the first 3 single-choice trials for which we randomly selected a particular tiger's scat as the test scat. For each dog, we used only those tigers whose scats we had randomly selected $\geq$3 times to be used for the test scat and we used only the first 3 trials for that tiger conducted on different days. For cross-testing, we calculated the proportion of tigers that were correctly identified by $\geq$2 out of 3 dogs in single-choice trials when we randomly selected a particular tiger's scat as the test scat and at least 3 dogs conducted the trial on the same day.

Double-choice tests.—In field studies, a test sample will not always belong to a tiger in the scent collection, but might instead be a new or as yet unrecorded individual. However, in law enforcement training it has been shown that error rate of dogs increases substantially when they are requested to match scents when there is no correct choice (Schoon 1998, Schoon and Haak 2002, Jenkins 2004). To avoid this situation, we trained dogs to expect $\geq$1 and sometimes 2 correct matches during a trial (Sokolov et al. 1990). A double-choice scenario mimics how actual tests to compare unknown scats would be conducted (i.e., with a new scat split into 2 scent jars [one as the test scat] and presented in a scent lineup composed of scats from a few tigers who may be a correct match and a few other tigers who are not matches). This design ensures one match, and allows the dog to select any additional matches that it can detect.

We used 3 dogs (3, 4, and 5) to identify 5 tigers from 17 scats to examine accuracy rates of dogs at choosing 2 correct matches in a scent lineup. We used scats from wild tigers for which we had $\geq$2 different scats so that scats from the same individual tiger were in the same scent lineup (when 3 scats were not available, the second match represented a subsample of the scat in the test jar). We composed the scent lineup of a random selection of 5 other scats from our total collection. In double-choice trials, if the dog sat in front of both correct choices, we considered it a correct identification, but if the dog sat in front of the wrong jars or only 1 of the 2 correct choices, we recorded it as a failure.

Effect of scat age in identifying tigers.—To determine if scat age affected accuracy of dogs, we tested 4 dogs' (dogs 2–5) ability to identify 11 scats collected from one radio-collared tiger over a 4-year period. Dogs were already familiar with 5 of the old scats (which we had collected between Feb 2000 and Mar 2001 and presented to them in previous tests), but had never been exposed to 6 new scats that we collected between December 2003 and March 2004. In the first trial for each dog, we exposed dogs to one randomly selected old scat in the test position and one randomly selected new scat in combination with 6 other randomly selected scats from other tigers in a standard scent lineup. After each trial, we moved the scat from the scent lineup to the test position and we randomly selected another scat from the opposite group (either old or new) for the lineup (along with 6 other randomly selected scats from other tigers) until we had used all 11 scats (10 trials each for 4 dogs).

Data Analysis

We used chi-square analyses to test the hypothesis that our dogs would make correct choices more than expected by chance ($P > 0.05$). In single-choice tests, the probability that a dog could randomly match a pair from a set of 7 was 1/7 = 14.3%. For double-choice tests, the probability was 1 out of 21 combinations (unique combinations of 2 selected from 7) = 4.8%. We calculated the percentage of correct choices and standard error from the total trials for each dog (accuracy rate) for both single- and double-choice tests and for repeated and cross-trial tests. We compared accuracy rates among dogs using analysis of variance and protected *t*-tests.

Table 1. A description of tiger and their scats used to conduct accuracy trials conducted between December 2002 and March 2005 near the Lazovsky State Nature Zapovednik in the Russian Far East.

Tiger	Source	Sex	Age	No. of scats	Duration between first and last scats	Prey remains in scats
1	radiocollared	M	sub-ad	2	3 months	wild boar, raccoon dog
2	radiocollared	M	sub-ad	3	3 months	red deer, domestic dog
3	radiocollared	F	ad	1	na	red deer
4	radiocollared	F	sub-ad	2	4 months	unidentified, red deer
5	radiocollared	F	ad	1	na	roe deer
6	radiocollared	M	ad	2	3 weeks	seal, raccoon dog
7	radiocollared	F	ad	11	4 yr	wild boar, red deer
8	unmarked[a]	unk[b]	unk	1	na	red deer
9	unmarked[c]	M	ad	2	≤24 hr	wild boar
10	unmarked[c]	F	ad	2	≤24 hr	sika deer
11	unmarked[d]	M	ad	1	na	red deer
12	Circus	M	ad	1	na	unk[e]
13	Circus	M	ad	2	24–36 hr	unk[e]
14	Circus	M	ad	2	24–36 hr	unk[e]
15	Circus	M	ad		24–36 hr	unk[e]
16	Minsk zoo	F	sub-ad	3	≤72 hr	unk[e]
17	Lepidski zoo	F	ad	4	72 hr	unk[e]
18	Perma zoo	M	ad	3	≤72 hr	unk[e]
19	Abakan zoo	F	ad	1	na	unk[e]
20	Moscow zoo	M	ad	1	na	unk[e]
21	Moscow zoo	F	ad	1	na	unk[e]
22	Leningrad zoo	M	ad	1	na	unk[e]
23	Leningrad zoo	F	ad	1	na	unk[e]
24	Utyos wildlife rehabilitation center	M	ad	3	≤72 hr	bear sp.
25	Utyos wildlife rehabilitation center	F	ad	5	≤2 weeks	domestic pig, deer sp.

[a] Ussuriski State Nature Zapovendik.
[b] Unknown.
[c] Lazovski State Nature Zapovednik.
[d] Khaborovski Krai.
[e] Captive tigers were fed meat from domestic and wild species but we were often unable to identify the contents in scats.

RESULTS

Scats

We acquired 58 scats from 25 tigers for use in accuracy trials (Table 1). Sex and age of tigers varied as well as the prey content in the scats. The time interval between depositions of multiple scats from single individuals varied from 2 weeks to 4 years for 5 wild radiocollared tigers. From a total sample of 58 scats, we identified 3 (one scat each from circus Tigers 13, 14, and 15; Table 1) as inappropriate for identification trials because the dogs were attracted to them for no apparent reason; we did not use them in test trials. In contrast, we used 95% of the scats that we collected (55 of 58 scats total) in the trials.

Trial Results

Single-choice tests.—We conducted 521 randomized and independent trials to assess accuracy of dogs to identify tigers from scat. Dogs correctly selected 1 of 7 scats to match the test scat at an average rate of 87% (SE ±1.4%, $n = 521$ trials). Each of the 5 dogs made correct choices significantly better than expected by chance (Table 2). There was no difference in mean percentage of correct choices made between dogs ($F_{4,516} = 1.13$, $P = 0.3394$) and we combined data for all dogs in subsequent tests.

Repeated and cross-tests.—Four dogs (dogs 1–4) correctly selected 1 of 7 scats to match the test scat in at least 2

Table 2. The performance (% of correct choices and SE from the total trials and χ^2 results used to test the hypothesis that dogs could make correct choices more than that expected by chance; 14.3%) of 5 dogs at making individual Amur tiger identifications by matching a test scat to a scat of the same tiger in a scent lineup, in single-choice test trials conducted between December 2002 and March 2005 near the Lazovsky State Nature Zapovednik in the Russian Far East.

Dog	*n* trials	Correct choices	Incorrect choices	$\bar{x}$ %	SE	*P*	χ^2_1
1[a]	108	96	12	89	3.0	≤0.001	507.9
2[b]	191	170	21	89	2.3	≤0.001	882.1
3[c]	98	81	17	83	3.7	≤0.001	374.1
4[c]	91	78	13	86	3.6	≤0.001	379.2
5[d]	33	26	7	79	7.2	≤0.001	103.9

[a] The dog was 2–3 yr of age when used in trials.
[b] The dog was 2–4 yr of age when used in trials.
[c] The dog was 1–2 yr of age when used in trials.
[d] The dog was 0.75–1 yr of age when used in trials.

of 3 repeated single-choice trials for each tiger at an average rate of 98% (SE ±1.6%, n = 86 sets of repeated trials). Dogs 1 and 2 both had an accuracy of 100% (dog 1 $n = 20$ tigers, dog 2 $n = 25$ tigers); dog 3 was accurate at an average rate of 95% (SE ±4.5%, $n = 22$ sets of repeated trials) and did not correctly identify one captive tiger; and dog 4 was accurate at an average rate of 95% (SE ±5.3%, $n = 19$ sets of repeated trials) and did not correctly identify one wild tiger. We did not use dog 5 because sample sizes of repeated trials for that dog were too small.

In cross-tests, 20 of 22 tigers (91%) were identified correctly by ≥2 out of 3 dogs (any 3 of dogs 2–5) in single-choice trials conducted on the same day for a given tiger. Only one scat was consistently mismatched with the wrong (but same) tiger in a cross-test (i.e., one scat from a wild radiocollared tiger was identified as another radiocollared tiger by 3 different dogs on the same day; however, that tiger was not misidentified by any dog in repeated tests).

Double-choice tests.—Dogs correctly identified both samples in the lineup correctly in 84% of the trials (SE = 5.3%, 41 correct choices in $n = 49$ trials), with 100% of the mistakes occurring when dogs sat next to only one correct jar (8 incomplete choices).

Effect of scat age in identifying tigers.—Four dogs were able to match 11 scats deposited over a 4-year period from tiger 7 (Table 1) with an accuracy of 100% ($n = 40$ trials).

Variation in dog behavior and sources of error.—Although the results of accuracy trials were similar for all 5 dogs, the length of their working lives varied because some dogs lacked the temperament to sustain motivation for such repetitive and controlled work. For example, dog 1 worked effectively for about 1 year until he lost interest and simply refused to smell test jars. Two additional German shepherd mixes lacked the temperament to finish the training program and were never tested. Dog 2, our oldest and most experienced dog (Table 2), was our most accurate dog her first year (95.8% accuracy, SE = 4%, $n = 118$), but she began showing signs of boredom after several months of work and her performance decreased to a mean accuracy of 78.1% (SE = 9.6%, $n = 73$) in her second year. Dogs 3 and 4 continued to work with high motivation even after 1.5 years of work. Dog 5 began testing at the youngest age (6 months), yet remained strongly motivated at the age of 1.5 years.

Dogs made 4 types of mistakes. For single-choice tests mistakes included 1) sitting next to the jar adjacent to the correct match (50% of all mistakes), 2) sitting next to the jar in the position that had been the correct match in the previous trial (6% of all mistakes), and 3) sitting next to the wrong jar for an unapparent reason (44% of all mistakes). The fourth type of mistake was to sit next to only 1 of 2 correct choices in double-choice tests.

DISCUSSION

All the dogs we trained identified individual tigers from scent in scat with a high degree of accuracy even though they were of different breeds, ages, and working styles. Dogs identified a variety of tigers from scats that differed in age and prey content and they often corrected mistakes made during one trial in repeated tests. This suggests that most of the mistakes may be due to training deficiencies (e.g., a dog rushes to sit after finding the scent and, hence, sits at the wrong jar), or trial design (e.g., too much scent in the room might confuse the dog) rather then an inability to recognize and match individual scent.

Careful selection, monitoring, and maintenance of individual dogs can likely increase accuracy and working life span of dogs, thus avoiding a large turnover and the need to constantly train new cadres of working dogs. For example, choosing dogs that have a great obsession with food or a toy object, coupled with a strong search drive may contribute to those dogs maintaining a consistent motivation to perform such repetitive tasks. Selecting older dogs (≥1 yr old) may have improved our "read" on the dog having the correct qualities needed for scent-matching work. It is possible that some of our dogs, selected as pups, did not possess the best qualities needed for such work and that our accuracy rates would have improved had we selected older dogs. Even so, after some of our trained dogs started showing signs of boredom, we changed training and practice protocols and found that dogs maintained better motivation if trials were interspersed with lots of play, if dogs were consistently rewarded with lots of enthusiasm, and if dogs were never harshly corrected after an incorrect choice. We also found that diversifying protocols also helped sustain motivation. For example, sometimes we set up training trials that included unfamiliar scents in the lineup including but not limited to catnip, tea, domestic animal scat, sika deer hair, aluminum foil, flowers, etc. This approach appeared to increase working longevity of our 3 youngest dogs.

Understanding the kinds of mistakes made by dogs is important in interpreting results and avoiding mistakes in future studies. During accuracy trials we treated all dogs the same to minimize variation. A better approach for field studies, however, may be to invoke more flexibility to treat each dog as an individual, thereby increasing accuracy. For example, one of our dogs was more strongly motivated when presented with fewer choices in the scent lineup or when the scats were placed farther apart. Other dogs were better motivated with more scats and more diversity. We also suggest that high energy breeds be allowed to exercise before performing scent trials so that they can perform more methodically.

Over half (56%) of the mistakes made by our dogs involved scats from captive tigers; fewer mistakes were made identifying wild tigers. Dogs possibly had a harder time working with scats from captive tigers because they had stronger odor and were often collected wet from cages, whereas scats collected in nature had time to air dry and contained more nonabsorbent hair and bone, which might hold less scent strength. We found that we could partially alleviate this problem by air-drying the scats for 2–3 days before using them in a trial, and by placing a minimal amount of scat or scent in each jar. Other probable causes could be similarities in living condition and diets of captive tigers, or that captive tigers were closely related, making differentiation more difficult.

In our study, using a design that relied on repeated and cross-tests to validate identifications greatly decreased the probability of error. Our dogs' accuracy greatly improved when identifications were based on repeated tests conducted on different days. In contrast, accuracy was less improved with cross-tests conducted on the same day using 3 different dogs. Perhaps dogs are affected by ambient conditions on one day that cause them to make mistakes. Therefore, we recommend that identifications be based on cross-tests using repeated tests (conducted on different d for each dog) of 2–3 dogs.

Ideally, the results of dogs used to identify unknown scats of individuals from species in the wild should be randomly compared to results of genetic analysis, if possible. This would allow researchers to keep track of varying performances by dogs, and make sure counts of individuals used for population estimates are accurate. This may not, however, be a viable option for some species, including Amur tigers, for which genetic identifications of individuals are unavailable. In those cases, we recommend using scent-matching dogs in conjunction with another method of field identification that will provide some degree of confirmation of the quality of identifications made by dogs and aid in accumulating a reference scat collection (e.g., track measurements [Kerley et al. 2005, Sharma et al. 2005] or locations of radiocollared animals).

MANAGEMENT IMPLICATIONS

Using scent-matching dogs to match scats is a noninvasive and fairly reliable approach to identifying individual tigers and, presumably, other animals as well. Using this method in conjunction with mark–recapture to estimate population sizes (Karanth and Nichols 2002) of Amur tigers, as well as other large carnivore species and tiger subspecies, may be a useful technique for estimating abundance in the wild, and may represent an alternative to genetic analysis that are used in conjunction with hair- and scat-sampling schemes (Taberlet et al. 2001) when DNA genotyping for individual recognition is impractical or ineffective. Additionally, our data show that at least some tigers can be identified from scats even when they are deposited 4 years apart. Hence, just as with genetic identification, identification of scats by dogs could be used with mark–recapture models that assume populations are closed by collecting scats in a short time interval, as well as open population models by using scats collected in different seasons or years. Our sample size, however, was limited to only one tiger whose scats were deposited 4 years apart and this needs further study with more samples.

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