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Comparison of Scent Lures on Captive Fosa (*Cryptoprocta ferox*): Implications for Field Methods

Cullen C. Anderson[1], Zheran Wang[2], Zach J. Farris[3]

[1.] *Auburn University, School of Forestry and Wildlife Sciences, Auburn, AL, 36832*
[2.] *Auburn University, Department of Mathematics and Statistics, Auburn, AL, 36832*
[3.] *Appalachian State University, Department of Health & Exercise Science, Boone, NC 28608*

***Corresponding Author:** Cullen C. Anderson, Auburn University, School of Forestry and Wildlife Sciences, Auburn, AL, USA. cca0020@auburn.edu*

ABSTRACT

Identifying scents that are most effective at luring specific carnivores is important for improving capture efforts in the field and making informed conservation and management decisions. However, knowledge on effective and preferred scents for fosa (Cryptoprocta ferox) is lacking, thus limiting field-based research efforts. To combat this absence of information, we conducted the first study of fosa scent preferences. We used a rank-based system to analyze fosa scent preference with six different scents (predator bait, weasel lure, catnip, deodorant, cologne, fish oil) by time in contact, the number of contacts, and the behaviors displayed with each scent with a captive fosa at Zoo Atlanta. Our findings suggest weasel lure and predator bait could act as effective scent lures for fosa. By contrast, cologne may act as a deterrent to fosa. Our findings warrant further investigation of fosa scent preferences across multiple zoos and in field studies on wild fosa populations to ultimately improve conservation of this threatened carnivore and the biodiverse hotspots it inhabits.

Keywords: *Attractant, Bait, Carnivore, Conservation, Madagascar, Zoo*

INTRODUCTION

Carnivores are among the most difficult groups of animals to study in the wild due to their large individual ranges, low population densities, and their cryptic, elusive, or nocturnal behavior [1-4]. Thus, in recent decades, researchers turned to trail cameras to study carnivores globally; however, cameras are stationary and rely on the assumption that the target species, if present in the area, will be detected by the camera.

While strategic camera placement along wildlife corridors, trails, and sources of food or water can improve the probability of detection [5], individuals of a target species may still be missed. To improve the probability a target species will be captured, researchers may use scent lures (hereafter "scents") to attract target species to camera sites [6]. Historically, hunters and trappers used scents to live-trap carnivores, but information on the effectiveness of those scents was mostly anecdotal [7].

While researchers have documented numerous effective scents for carnivores world-wide, no one scent can effectively lure all carnivores (e.g. a scent that is effective for canines may not be effective for felines or ursids)[8]. As a result, identifying scents that are most effective for specific taxa, family, or species is important for improving capture efforts in the field.

Family Eupleridae, the carnivore group endemic to the island of Madagascar, represents one of the least known and most threatened groups of carnivores in the world [9]. The taxonomic placement of this family of carnivores is still debated today, due to the isolation of this group over the last tens of millions of years [10].

The fosa (Cryptoprocta ferox), the largest member of Eupleridae, is the most wide-spread carnivore in Madagascar and, as a result, is often considered an "umbrella species" in the ecosystems they inhabit [11-12]. Despite this, fosa are one of the least-studied carnivores in the world, and their vulnerable status makes studying and managing them particularly important [9, 13]. This will ultimately lead to the protection of the flora and fauna that fall under their 'umbrella.' Identifying effective and preferred scents for fosa has gone unstudied, which leaves researchers with inadequate information to effectively study these threatened carnivores in the wild.

The identification of an effective, fosa-specific scent will greatly improve efforts to photo- and live-capture individuals across Madagascar's forests. Because fosa do not have unique, distinctive pelage patterns, identifying individuals is difficult, making methods that improve detection and capture probabilities all the more important. Previous studies estimated fosa density by utilizing baits to improve detections and by using partially marked animals [6,14].

In turn, improving capture rates of fosa will lead to more accurate and reliable population estimates, which will improve conservation and management efforts throughout Madagascar. The goal of this study was to evaluate preference for predator scent on a captive fosa at Zoo Atlanta, US with the aim of identifying an effective scent to use in field studies in Madagascar.

Our objectives were to: 1) determine if fosa spent significantly more time in contact with a particular scent; 2) determine if fosa had significantly more contacts with a particular scent; and 3) determine if fosa showed different behaviors towards a specific scent.

MATERIALS AND METHODS

Study Area

From 30 October 2016 to 9 April 2017 we carried out a behavioral study on a single captive male fosa at Zoo Atlanta, US. Zoo Atlanta was the only zoo that was accessible to us that housed a fosa, and we did not receive replies from requests for remote participation in the study by other zoos. The fosa occupied an outdoor cage measuring approximately 7.3 m by 5.2 m by 4.0 m. The enclosure featured a wood mulch floor, wooden climbing structures, two metal support columns, bushes, and a false rock wall along the rear side (Figure 1). We observed fosa behavior from the public viewing area of the enclosure, approximately 4 m from the center of the enclosure. Due to the outdoor setting, temperatures varied across the entire study, ranging from 30 °C to 10 °C. We did not conduct trials at temperatures below 10 °C on cloudy days, because the fosa was given access to its indoor enclosure which prevented observation. We did not conduct trials during December or January due to weather constraints, particularly cold temperatures, nor did we conduct trials during precipitation events.

Fig1. *Fosa enclosure (7.3 m by 5.2 m by 4.0 m) at Zoo Atlanta, US as seen from the public viewing area. The enclosure featured a wood mulch floor, wooden climbing structures, two metal support columns, bushes, and a false rock wall along the rear side Observers stood approximately 4 m from the center of the enclosure along the fence in the foreground.*

Scents

We selected scents based on expert advice and products used in studies involving scents on felines and herpestids due to the close relatedness both families share with Eupleridae. We used predator bait (Hiawatha Valley Predator Bait; Minnesota Trapline Products, Inc.; Pennock, MN, USA), weasel lure (Lenon's Super All Call Weasel Lure; Lenon Lures; Au Gres, MI, USA), catnip (KONG Naturals Catnip Spray; Kong Co.; Golden, CO, USA), deodorant (Brut's Men's Deodorant; Helen of Troy, Ltd.; El Paso, TX, USA), cologne (Calvin Klein 1 Cologne; PVH Corp.; New York, NY, USA), and fish oil (Nature Made Fish Oil; Pharmavite, LLC.; Northridge, CA, USA). Predator bait, weasel lure, and catnip were recommended by a wildlife biologist with extensive experience in trapping mammals [15]. We also selected catnip due to its frequent use in feline detection studies [16-18].

We chose deodorant and cologne because they have shown potential to be effective in luring felines [16,19-20]. We used fish oil because fish-based lures showed potential to be effective in luring both felines and herpestids[20-21].

We tested the aforementioned scents for nine weeks. Based on the results of these trials and based on additional, post-hoc recommendations from predator bait/lure manufacturers, we selected five additional scents to test. We ran these trials for three weeks. We used the following Lenon'sLures products: weasel lure,Bobcat Nature's CallLure, Bobcat Super All CallLure, Mink Nature's Call Lure, Mink Super All CallLure, and Mink Super Range All Call Lure. We selected mink scents because minks are mustelids like weasels.

We applied all scents during all trials to 10.2 cm x 2.5 cm x 15.2 cm untreated oak or poplar blocks using foam brushes dipped once in the scent. We randomized oak and poplar blocks for each scent and trial. We sprayed cologne and catnip twice on to their corresponding blocks. Because the fish oil came in 500mg tablets, we cut one tablet open and rubbed it on to the corresponding block. We chose a two-letter acronym for each scent (e.g. weasel lure = WL) and wrote it in sharpie on the longest sides of each block. We also used an unscented control block on which we wrote "control" in place of an acronym. The same blocks, matched with the same scents, were used throughout data collection when possible. We replaced blocks only when the fosa heavily damaged the original block with chewing.

Data Collection

We used a two-observer method to assess fosa preference and behavior towards the scents. To reduce stress on the animal, we conducted two observation periods per day, one day each weekend during the study period with each observation period lasting an hour (e.g. total of two observation hours per weekend). We left the time of each observation period at the discretion and availability of the fosa keepers, but they typically occurred at 11h00 and 13h00. We did not consider time of day to be an important factor affecting fosa activity, since fosaare active during daylight hours; although they are largely crepuscular [22].A number of studies demonstrated fosa show wide-ranging, variable activity patterns across the diel cycle [22-24]. For each trial, we placed four blocks in the enclosure; three scents selected randomly and one control. For the second trial, we selected three previously unused scents to place with the control in the enclosure. We tested each scent the same number of times, and we randomized the placement or organization of blocks within the enclosure during each individual trial. This method allowed us to test all combinations of scents multiple times over the course of the study. We stored the scents separately from the fosa enclosure to prevent the fosa's exposure to the scents outside of data collection periods, and we stored the blocks individually in sealed ziplock bags inside a closed container within the keeper facility of the enclosure. We prepared the blocks in the keeper facility of the enclosure on the day on which they were tested.

At the beginning of each trial, both observers recorded the date, start time, observer names, and the scents used. Observer one took focal samples at one-minute intervals for up to one hour, recording information on: contact with scent (Y,N), sleep/rest (Y,N), standing (Y,N), pacing (Y,N), eating (Y,N), playing (Y,N). We defined contact with scent as any instance in which the fosa directly interacted with a scent (e.g. pawing, biting, licking, or smelling a block was considered contact, but pacing over the blocks without stopping was not). We detailed the type of contact, such as sniffing, licking, or chewing, in the notes section of the data sheet. We defined sleep/rest as any inactivity in which the fosa was sitting or lying down and not interacting with any scents. We defined pacing as repetitively walking circuits within the enclosure. We noted non-pacing walking in the notes section of our data sheets. We defined playing as intentional interactions with objects, including the blocks, using paws or mouth (e.g. chewing on a ball or batting at bushes). If we observed an activity that did not fit into any of the listed activities, such as climbing on branches or defecating, we described the activity in a notes section of the data sheet. We recorded these data/behaviors regardless of the fosa's proximity to the scents. Observer two made detailed behavioral observations when the fosa was in contact with a scent, the amount of time spent in contact with the block/scent, what scent the fosa interacted with, and additional information on fosa behavior. The observer also recorded if the fosa was in contact with the block directly or was in contact with a previous location of the block after the block had been moved. After the end of the first trial, blocks were left in the enclosure for an additional hour until the start of the second trial in order to reduce disturbance to the fosa and use of keepers. Keepers collected and stored the blocks at the end of second trial. The Animal Care Institution at Auburn University (permit no. 2016-2959) and Zoo Atlanta Research group approved the research methods used in this study.

Data Analysis

Because the fosa rarely came into contact with a scent at the one-minute intervals collected by observer one, we did not use observer one data to evaluate scent preference. Using observer two data, we accomplished our three objectives by comparing the fosa's behavior to the scents. Our objectives were to: 1) determine if the fosa spent significantly more time in contact with a particular scent; 2) determine if the fosa had significantly more contacts with a particular scent; and 3) determine if the fosa showed different behaviors towards a specific scent.

To test our first objective, we ranked each scent by the amount of time, in seconds, the fosa spent with each scent. We used a Friedman ANOVA test to determine if at least one scent was significantly different from the others. We then used a Tukey test to determine which scents were significantly different. We then used a power test to determine the power of the Friedman ANOVA test result.

To test our second objective, we compared each scent by the number of contact events. We defined "contact event" as any contact with a scent, regardless of length of time of each event (e.g. a one-second or one-minute contact event would both be counted as one event each). We used a one-way ANOVA to determine if at least one scent was significantly different from the others. We then used a Tukey test to determine what scents were significantly different. We then used a power test to determine the power of the one-way ANOVA test result.

We weighted each behavior based on the amount of energy exerted (ex. sniffing = 1; licking =2; pawing = 3; chewing = 4; and picking up = 5), where increasing numbers represent greater physical exertion. We chose these weights based on the increased physicality of the behaviors observed (e.g. chewing a block requires more energy and interaction with the block than sniffing). We then added the weights of all of the behaviors observed with each scent together and performed a one-way ANOVA test to determine if at least one scent was significantly different from the others. We then used a Tukey test to determine which scents were significantly different. We then used a power test to determine the power of the one-way ANOVA test result.

To represent the weights of the ranking system for behavior, we created a "behavior score" for each scent (Figure2; Table 3). We calculated the behavior score by multiplying the weight of a given behavior by the number of instances that behavior was observed in each trial and summing the products of the multiplications. We did not use this score in data analysis; its function is to reflect our ranking system and increase understanding of raw data.

$$Behavior\ Score = \sum(Behavior\ Weight \times Number\ of\ Occurrences$$

Figure 2. The equation we used to calculate a number representative of the effects our weighted system on the raw data. We multiplied the weight of a given behavior by the number of instances that behavior was observed in each trial. We then summed the products of the multiplications. To determine statistical preference for a particular scent, we only analyzed data from the trials conducted for the first nine weeks. We did not analyze data collected from the additional three weeks as we were not able to conduct a sufficient number of trials for statistical analysis.

RESULTS

Between 30 October 2016 and 16 March 2017, we completed a total of nine trial days and eighteen observation periods with the initial scents (predator bait, weasel lure, catnip, deodorant, cologne, fish oil). We presented each scent for a total of nine hours, whereas we presented the control for eighteen hours due to its use in both observation periods per trial day.

From 26 March 2017 to 9 April 2017 we tested the additional scents, along with the weasel lure, for three trial days and six observation periods. We presented each scent for a total of three hours, whereas we presented the control for six hours due to its use in both observation periods per trial day. We did not analyze the results of the additional scent trials because of an inadequate amount of data for statistical analysis.

Objective One: Contact Time

For objective one, we found that the most preferred scents (based on total time) were weasel lure (1,679 seconds), fish oil (436 seconds), and predator bait (403 seconds). Of the total time in contact with a scent, the fosa spent 64.39% with weasel lure, 16.72% with fish oil, and 15.49% with predator bait (Table 1). We found that the least preferred scent (based on total time) was cologne (9 seconds). Of the total time in contact with a scent, the fosa spent 0.34% with cologne (Table 1).

Table1. *The total number of seconds captive fosa spent with each scent during each trial period (1-9) carried out at Zoo Atlanta, US. Output also includes the total number of seconds with scents for each trial, percent total (compared to all other scents), and the average amount of time per trial for each scent.*

Trial	Weasel Lure	Predator Bait	Deodorant	Cologne	Fish Oil	Catnip	Control	Total
Trial 1	691	16	15	2	10	0	6	740
Trial 2	297	35	4	0	20	1	2	359
Trial 3	105	12	1	0	27	1	1	147
Trial 4	49	6	1	1	2	5	3.5	67.5
Trial 5	119	16	6	3	9	4	2	159
Trial 6	301	6	3	1	0	2	0.5	313.5
Trial 7	75	154	5	1	248	5	1	489
Trial 8	41	128	2	0	98	1	1	271
Trial 9	1	30	5	1	22	1	1.5	61.5
Total	1679	403	42	9	436	20	18.5	2607.5
% of Total	64.39%	15.46%	1.61%	0.34%	16.72%	0.77%	0.71%	100%
Average	186.56	44.78	4.67	1.00	48.44	2.22	2.06	289.7

A Turkey test revealed significant preference for weasel lure and predator bait over deodorant, catnip, and cologne (α<0.05, power>0.99; Appendix 1a). Neither of these scents showed significant difference from fish oil (Appendix 1a).

Objective Two: Number of Contacts

For objective two, we found that the most preferred scents (based on total number of contacts) were weasel lure (73), fish oil (30), and predator bait (26). Of the total number of contacts with a scent, the fosa spent 40.00% with weasel lure, 16.44% with fish oil, and 14.25% with predator bait (Table 2). We found that the least preferred scent (based on total number of contacts) was cologne with only 4.93% of the total number of contacts (Table 2). There were fewer contacts with cologne than the control.

Table2. *The total number of contacts captive fosa had with each scent during each trial period (1-9) carried out at Zoo Atlanta, US. Output also includes the total number of contacts with scents for each trial, percent total (compared to all other scents), and the average amount of contacts per trial for each scent.*

Trial	Weasel Lure	Predator Bait	Deodorant	Cologne	Fish Oil	Catnip	CONTROL	Total
Trial 1	13	3	2	2	4	0	2	26
Trial 2	19	1	4	0	5	1	2	32
Trial 3	4	3	1	0	5	1	0.5	14.5
Trial 4	11	6	1	1	2	1	1.5	23.5
Trial 5	12	2	4	3	4	4	2	31
Trial 6	4	1	1	1	0	2	0.5	9.5
Trial 7	3	3	1	1	1	2	1	12
Trial 8	6	5	1	0	7	1	0.5	20.5
Trial 9	1	2	5	1	2	1	1.5	13.5
Total	73	26	20	9	30	13	11.5	182.5
% of Total	40.00%	14.25%	10.96%	4.93%	16.44%	7.12%	6.30%	100%
Average	8.11	2.89	2.22	1.00	3.33	1.44	1.28	20.28

A Tukey test revealed significant preference for weasel lure over deodorant, catnip, and cologne (α<0.05, power=0.928; Appendix 1b). We did not find a significant difference between weasel lure and either predator bait or fish oil (Appendix 1b).

Objective Three: Behaviors

For objective three, we found fosa exerted greater energy in response to (based on behavior with scent block) weasel lure, predator bait, and fish oil. Weasel lure also had the highest count for every type of behavior (sniffing, licking, pawing, chewing, and picking up) compared to all other scents. As a result, weasel lure also had the highest weighted behavior score; more than three times the value of predator bait (the nearest ranked scent) (Table 3). We found that fosa exerted the least amount of energy in response tocologne. Cologne experienced the lowest amount of behaviors and had the lowest behavior score (Table 3). Fosa demonstrated only sniffing behavior towards cologne, deodorant, and catnip(Table 3). Sniffing was the most common behavior observed (n = 174.5) and picking up the block was the least observed (n = 4) (Table 3).A Tukey test revealed significant preference (based on weighted values) for weasel lure over all other scents, including predator bait ($\alpha<0.05$, power>0.99; Appendix 1c).

Table3. *The total number of behaviors captive Fosa exhibited towards each scent during trial periods (1-9) carried out at Zoo Atlanta, US. Output also includes the total number of instances we observed each behavior with scents, percent total and the behavior score for each scent. We did not incorporate behavior scores into data analysis.*

Behavior	Weasel Lure	Predator Bait	Deodorant	Cologne	Fish Oil	Catnip	Control	Total
Sniffing (1)	70	26	18	7	30	12	11.5	174.5
Licking (2)	16	7	0	0	6	0	0	29
Pawing (3)	22	8	0	0	4	0	0.5	34.5
Chewing (4)	12	1	0	0	1	0	0	14
Picking Up (5)	3	0	0	0	1	0	0	4
Total	126	42	18	7	42	12	12	256
Behavior Score	231	68	18	7	63	12	13	

Discussion

The goal of this study was to evaluate preference for predator scent lures on fosa with the aim of identifying an effective scent to use in field studies in Madagascar. We found that the fosa significantly preferred weasel lure and predator bait over other scents based on time in contact with scents, the number of contacts with scents, and behavior towards scents. By contrast, our data suggests that cologne potentially deterred the fosa. Because our subject sample size was one, we cannot conclude our results are representative of other fosa, captive or wild. We highly recommend further investigation of fosa scent preferences at other zoos with multiple fosa. Due to our limitations in sample size, we encourage additional field and captivity studies before making recommendations to field biologists studying wild fosa populations. Therefore, we suggest researchers develop experimental approaches for testing fosa scent preferences in the field. This study is the first to investigate fosa scent preferences, and future research on this topic may greatly improve field-based research and management strategies in Madagascar.

Though our analyses show both weasel lure and predator bait were significantly preferred, the raw data indicates a strong, though not significant, preference for weasel lure alone. We analyzed preference based on contact time by using ranks instead of values. As a result, we did not use raw data, which showed even stronger preference for weasel lure. For example, the fosa spent more than four times as many seconds with weasel lure as with predator bait over the course of the entire study, yet, statistically, they are not significantly different (Table 1). It should also be noted that fosa interacted longer with fish oil compared to predator bait (Table 1), yet fish oil was not identified as a preferred scent. Future studies should consider the required number of trials for accurate analyses with a values-based system using raw data.

Additionally, the raw data indicates potential habituation and shifts in preferences forscents as trials progressed. For example, total interaction time with weasel lure per trial decreased over the study (e.g. 691 seconds in trial 1 and 1 second in trial 9; Table 1). However, interaction with other scents increased over time, such as predator bait and fish oil (e.g. longest times spent with both scents were during trials 7 and 8; Table 1). We cannot conclude whether this variation in interaction represents habituation, changes in preferences, or any other response to repeated exposure to the same scents over time. However, we believe behavioral shifts over time are likely, potentially masking preferences that would be displayed more strongly during a shorter study period. Alternatively, shorter study periods may not be long enough to show preferences that are hidden by variability at small time scales. Future scent studies should consider these trade-offs.

During our observations, we noticed on multiple occasions that the fosa seemingly sniffed a location previously occupied by the weasel lure block (Appendix 2). This behavior occurred during observation periods in which the weasel lure was present and had been moved by the fosa. It also occurred in afternoon observation periods after the weasel lure block from the morning had been completely removed from the enclosure. We could not verify that the fosa was actually detecting remnants of weasel lure scent, but the behavior only occurred in locations weasel lure previously occupied. Though this behavior was not included in our data analysis due to our inability to verify its cause, it further suggests that weasel lure was strongly preferred over any other scent. Future studies should plan for this behavior and verify its authenticity for use in analysis.

For this study, we assumed that Zoo Atlanta's captive fosa scent preferences are representative of other captive fosa scent preferences and wild fosa scent preferences; however, testing across a larger sample size is needed to test this assumption. We assumed the subject's behavior with scents was not influenced by previous interactions with enrichment scents, nor was it influenced by the visual, auditory, and olfactory qualities of the outdoor enclosure. Regarding objective three, we assumed that different behaviors with scents were indicative of different levels of preference, and the physicality of each behavior was directly related to the behavior's assigned weight (e.g. chewing a block requires more energy and interaction with the block than sniffing). We assumed that any direct interaction with a scent (e.g. sniffing, licking, pawing, biting, or picking up a block, but not pacing over the blocks without stopping) was an indication of preference, and we observed no clear behavior that indicated a particular scent acted as a deterrent. However, our data suggests less preference for cologne than the unscented control block, so a study of fosa scent preference with a variety of colognes and deodorants should be conducted to determine if cologne has a deterrent effect on fosa behavior.

It may be possible that some behaviors we ranked with lower behavior or weighted scores actually correspond to greater preference (e.g. licking may show greater preference than pawing); however, we suggest our raw data on the count of individual behaviors further support our findings. Weasel lure had the highest count of all behaviors compared to other scents, and its number of individual behaviors and resulting behavior score were more than three times that of predator bait and seven times higher than fish oil, catnip, and the control.

Field research and population estimates for wild fosa populations are generally absent or insufficient for most protected areas in Madagascar. This problem is exacerbated by the lack of knowledge on effective and preferred scents for this threatened carnivore. This study was the first to examine fosa scent preferences, and our findings suggest that weasel lure could act as an effective scent lure for field studies aiming to live or photo capture fosa. However, we must stress our limited sample size means we cannot make definitive inferences from our results about the scent preferences of other captive or wild fosa. Previous studies of wild fosa using camera traps showed fosa probability of detection was 0.15 (± SE 0.02) across the Masoala-Makira landscape and 0.15 (± SE 0.01) across the Ranomafana National Park landscape [25-26]. Improving these low probabilities of detection will bolster our efforts to estimate numerous population parameters (i.e. occupancy, density, survival) and improve precision of these estimates. Fosa do not have unique pelage patterns, making identification of individuals difficult and increasing the need for higher detection rates for population studies. For example, in their efforts to estimate fosa density using partially marked individuals, Murphy et al. [14] had to expel numerous fosa captures from analysis due to the authors' inability to accurately identify individuals. Gerber et al. [6] found that using bait or lures in front of camera traps across the Ranomafana National Park region improved detection probabilities and, in turn, improved precision of density estimates for spotted fanaloka(Fossa fossana). Given the call for additional research on fosa populations across Madagascar to improve management and conservation efforts for this threatened carnivore [6, 9, 14, 27], we encourage future zoo-based research to conduct similar studies of fosa scent preferences. Furthermore, field-based researchers should investigate wild fosa preferences for commercially available scents. For live capturing, we (Farris) tried other scents that included a mix of rotten fish and chicken parts in water, which provided no live captures of fosa over a two-week period. For camera trapping, Gerber et al. [6] used raw chicken staked to the ground, which greatly improved detection by keeping the animal directly in front of the camera for prolonged periods of time. The scents we tested on the captive fosa would be easier and more desirable to work with in the field compared to these examples. An effective, fosa-specific scent will greatly improve these efforts. Moreover, it will also likely improve detection of co-occurring carnivores such as spotted fanaloka, falanouc (Eupleresgoudotii), ring-tailed vontsira(Galidia elegans), broad-striped vontsira (Galidictisfasciata), and brown-tailed vontsira (Salanoia concolor), all of which have low detection rates [25,28]. Employing attractants, particularly food lures, in field studies presents potential bias in results, namely that the use of such attractants may permanently alter the number of individuals in the sampling area or change the habitat associations of individuals [29]. Habituation to artificial food and human presence is also a potential consequence [29]. However, because scent-based attractants do not provide a resource otherwise limited in the environment (i.e. nutritional supplementation), scent attractants are less likely to cause issues of bias and habituation [29]. Furthermore, Gerber et al. [6] found food lures did not affect immigration or emigration of Malagasy civets but did increase the precision of density estimates. Therefore, increasing detection using scent attractantswill likely provide more accurate population parameter estimates for all carnivores without significantly altering any individual’s behavior or population demographics. Fosa are one of the least-studied carnivores in the world, and their vulnerable status and ‘umbrella species’ designation makes researching and conserving them particularly important [9, 13]. The results of this study will better inform field researchers studying wild fosa and improve their efforts to increase captures and detections. As a result, this may result in better informed conservation and management programs for wild fosa in Madagascar which will ultimately lead to the protection of the flora and fauna that fall under their ‘umbrella.’

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REFERENCES

[1] Garshelis DL. Mark-recapture density estimation for animals with large home ranges. In: McCullough D, Barrett RH. (eds.) Wildlife 2001: populations. Barking, United Kingdom: Elsevier Science Publishers LTD; 1992. p.1097-1111.

[2] Balme GA, Hunter LT, Slotow R. Evaluating methods for counting cryptic carnivores. Journal of Wildlife Management. 2009;73(3), 433-441.

[3] Obbard ME, Howe EJ, Kyle CJ. Empirical comparison of density estimators for large carnivores. Journal of Applied Ecology. 2010;47(1), 76-84.

[4] Ripple W, Estes J, Beschta R, Wilmers C, Ritchie E, HebblewhiteM,…Wirsing A. Status and ecological effects of the world's largest carnivores. Science. 2014;343(6167), 151-163.

[5] Cusack JJ, Dickman AJ, Rowcliffe JM, Carbone C, Macdonald DW, Coulson T. Random versus game trail-based camera trap placement strategy for monitoring terrestrial mammal communities. PLoS ONE. 2015;10(5).

[6] Gerber BD, Karpanty SM, Kelly MJ. Evaluating the potential biases in carnivore capture–recapture studies associated with the use of lure and varying density estimation techniques using photographic-sampling data of the Malagasy Civet. Population Ecology. 2012;54(1), 43-54.

[7] Schlexer FV. Attracting animals to detection devices. In Long R, MacKay P, Ray J, Zielinski W. (eds.) Noninvasive Survey Methods for Carnivores. Washington, DC, United States of America: Island Press; 2008. p. 263-264.

[8] Schemnitz SD, Batcheller GR, Lovallo MJ, White HB, Fall MW. Capturing and handling wild animals. In Silvy NJ (eds.) The Wildlife Techniques Manual. Baltimore, United States of America: John Hopkins University Press; 2012. p. 232-269.

[9] Brooke ZM, Bielby J, Nambiar K, Carbone C. Correlates of research effort in carnivores: body size, range size and diet matter. PLoS ONE. 2014;9(4).

[10] Veron G, Dupré D, Jennings AP, Gardner CJ, Hassanin A, Goodman SM. 2017. New insights into the systematics of Malagasy mongoose-like carnivorans (Carnivora, Eupleridae,

Galidiinae) based on mitochondrial and nuclear DNA sequences. Journal of Zoological Systematics and Evolutionary Research. 2017;55(3), 250-264.

[11] Woodroffe R. Strategies for carnivore conservation: lessons from contemporary extinctions. In Gittleman J. (eds.) Carnivore Conservation (1st ed.). Cambridge, United Kingdom: Cambridge University Press; 2001. p. 60-92.

[12] Farris ZJ. Response of Madagascar's endemic carnivores to fragmentation, hunting, and exotic carnivores across the Masoala-Makira landscape, NE Madagascar. Blacksburg, VA: Virginia Polytechnic Institute and State University. Doctoral Dissertation; 2014.

[13] Hawkins F. Cryptoprocta ferox. Available from: http://www.iucnredlist.org/details/5760/0. [Accessed 13th September 2017].

[14] Steury T. Wildlife biologist. Personal Communication. August 2016.

[15] Castro-Arellano I, Madrid-Luna C, Lacher Jr TE, Leon-Paniagua L. Hair-trap efficacy for detecting mammalian carnivores in the tropics. Journal of Wildlife Management, 2008;72(6),1405-1412.

[16] Schmidt K, Kowalczyk R. Using scent-marking stations to collect hair samples to monitor eurasian lynx populations. Wildlife Society Bulletin. 2006;34(2), 462-466.

[17] Mallory FF, Carter RA, Fortier JL, Kenn IS, Weis L, White, BN. Cougars, Puma concolor, in Ontario: additional evidence. The Canadian Field-Naturalist. 2012;126(4), 320-323.

[18] Cove MV, Spinola RM, Jackson VL, Saenz J. Camera trapping ocelots: an evaluation of felid attractants. The Italian Journal of Mammalogy. 2014;25(2), 113-116.

[19] Hedges L, Morrant D, Campos-Arceiz A, Clements G. Feasibility of using scent-baited hair traps to monitor carnivore populations in peninsular Malaysia. Tropical Conservation Science. 2015;8(4), 975-982.

[20] Peters D, Wilson L, Mosher S, Rohrer J, Hanley J, Nadig A, . . . Jeffrey J. 2011. Small Indian mongoose – management and eradication using DOC 250. In Veitch C, Clout M,

[21] Towns D. (eds.) Island invasives: eradication and management. Gland, Switzerland: IUCN; 2011. p. 225-227.

[22] Farris ZJ, Golden C, Karpanty S, Murphy A, Stauffer D, Ratelolahy F, Andrianjakarivelo V, Holmes CM, Kelly MJ. Hunting, Exotic Carnivores, and Habitat Loss: Anthropogenic

[23] Effects on a Native Carnivore Community, Madagascar. PLoS ONE. 2015;10(9): e0136456.

[24] Gerber B. Comparing density analyses and carnivore ecology in Madagascar's southeastern rainforest. Blacksburg, VA: Virginia Polytechnic Institute and State University. Doctoral Dissertation; 2010.

[25] Farris ZJ, Gerber B, Valenta K, Rafaliarison R, Razafimahaimodison J, Larney E, . . .Chapman C. Threats to a rainforest carnivore community: a multi-year assessment of occupancy and co-occurrence in Madagascar. Biological Conservation. 2017;210, 116-124.

[26] Murphy A, Gerber B, Farris Z, Karpanty S, Ratelolahy F, Kelly M. Making the most of sparse data to estimate density of a rare and threatened species: a case study with the fosa, a little-studied Malagasy carnivore. Animal Conservation. 2018;21(6), 496-504.

[27] Farris ZJ, Kelly M, Andrianjakarivelo V, Ratelolahy F, Karpanty S, Holmes C.

[28] Confirmation of Brown-tailed Mongoose Salanoia concolor across Makira Protected Area: Photographic evidence from camera trapping. Small Carnivore Conservation. 2012;47, 82-86.

Appendix1a. *Tukey test for Time in Contact*

Comparisons significant at the 0.05 level are indicated by ***				
Scent Comparison	**Difference Between Means**	**Simultaneous 95% Confidence Limits**		
PREDATOR BAIT - WEASEL LURE	0.3838	-1.2810	2.0486	
PREDATOR BAIT - FISH OIL	1.1111	-0.6349	2.8572	
PREDATOR BAIT - DEODORANT	2.1667	0.4206	3.9127	***
PREDATOR BAIT - CATNIP	2.6111	0.8113	4.4109	***
PREDATOR BAIT - COLOGNE	3.7986	1.9988	5.5984	***
WEASEL LURE - PREDATOR BAIT	-0.3838	-2.0486	1.2810	
WEASEL LURE - FISH OIL	0.7273	-0.9375	2.3921	
WEASEL LURE DEODORANT	1.7828	0.1180	3.4476	***
WEASEL LURE - CATNIP	2.2273	0.5062	3.9483	***
WEASEL LURE - COLOGNE	3.4148	1.6937	5.1358	***
FISH OIL - COLOGNE	2.6875	0.8877	4.4873	***

Appendix1b. *Tukey test for Number of Contacts*

Comparisons significant at the 0.05 level are indicated by ***				
Scent Comparison	Difference Between Means	Simultaneous 95% Confidence Limits		
WEASEL LURE - FISH OIL	3.394	-0.804	7.592	
WEASEL LURE - PREDATOR BAIT	3.838	-0.360	8.036	
WEASEL LURE - DEODORANT	4.505	0.307	8.703	***
WEASEL LURE - CATNIP	5.102	0.762	9.442	***
WEASEL LURE - COLOGNE	5.602	1.262	9.942	***

Appendix1c. *Tukey test for Behavior*

Comparisons significant at the 0.05 level are indicated by ***				
Scent Comparison	Difference Between Means	Simultaneous 95% Confidence Limits		
WEASEL LURE - PREDATOR BAIT	16.141	0.961	31.322	***
WEASEL LURE – FISH OIL	18.586	3.405	33.767	***
WEASEL LURE - DEODORANT	24.364	9.183	39.544	***
WEASEL LURE - CATNIP	24.864	9.170	40.558	***
WEASEL LURE - COLOGNE	25.489	9.795	41.183	***

Appendix2. *Raw behavior data for each scent during trial periods (1-9) carried out at Zoo Atlanta, US.*

Trail	Time Period	Scent	Contacts	Time in Contact (s)	Sniffing	Licking	Pawing	Chewing	Picking Up	Return to Location
Trial 1 30 October 2016	AM	CONTROL	2	9	2	0	1	0	0	0
		DEODORANT	2	15	2	0	0	0	0	0
		WEASEL LURE	13	691	13	2	9	2	3	1
		COLOGNE	2	2	0	0	0	0	0	0
	PM	CONTROL	2	3	2	0	0	0	0	0
		PREDATOR BAIT	3	16	3	0	1	0	0	0
		FISH OIL	4	10	4	0	0	0	0	0
		CATNIP	0	0	0	0	0	0	0	0
Trial 2 6 November 2016	AM	CONTROL	0	0	0	0	0	0	0	0
		PREDATOR BAIT	1	35	1	1	1	0	0	0
		CATNIP	1	1	1	0	0	0	0	0
		COLOGNE	0	0	0	0	0	0	0	0
	PM	CONTROL	4	4	4	0	0	0	0	0
		DEODORANT	4	4	3	0	0	0	0	0
		FISH OIL	5	20	5	0	0	0	0	0
		WEASEL LURE	19	297	17	0	2	1	0	2
Trial 3 13 November 2016	AM	CONTROL	1	2	1	0	0	0	0	0
		WEASEL LURE	4	105	3	0	3	2	0	0
		PREDATOR BAIT	3	12	3	0	1	0	0	0
		COLOGNE	0	0	0	0	0	0	0	0
	PM	Control	0	0	0	0	0	0	0	0
		WEASEL LURE*	1	5	1	0	1	0	0	1
		DEODORANT	1	1	1	0	0	0	0	0
		FISH OIL	5	27	5	0	1	0	1	0
		CATNIP	1	1	1	0	0	0	0	0
Trial 4 20 November 2016	AM	CONTROL	2	6	2	0	0	0	0	0
		DEODORANT	1	1	1	0	0	0	0	0
		CATNIP	1	5	1	0	0	0	0	0
		COLOGNE	1	1	1	0	0	0	0	0
	PM	CONTROL	1	1	1	0	0	0	0	0
		WEASEL LURE	11	49	11	1	0	1	0	0
		PREDATOR BAIT	6	6	6	0	0	0	0	0
		FISH OIL	2	2	2	0	1	0	0	0
Trial 5 27 November	AM	CONTROL	3	3	3	0	0	0	0	0
		PREDATOR BAIT	2	16	2	0	0	0	0	0
		DEODORANT	4	6	4	0	0	0	0	0

Trail	Time Period	Scent	Contacts	Time in Contact (s)	Sniffing	Licking	Pawing	Chewing	Picking Up	Return to Location
2016		CATNIP	4	4	3	0	0	0	0	0
	PM	CONTROL	1	1	1	0	0	0	0	0
		WEASEL LURE	12	119	12	4	3	1	0	5
		COLOGNE	3	3	3	0	0	0	0	0
		FISH OIL	4	9	4	0	0	0	0	0
Trial 6 19 February 2017	AM	CONTROL	1	1	1	0	0	0	0	0
		CATNIP	2	2	2	0	0	0	0	0
		COLOGNE	1	1	1	0	0	0	0	0
		WEASEL LURE	4	301	4	3	3	3	0	0
	PM	CONTROL	0	0	0	0	0	0	0	0
		PREDATOR BAIT	1	6	1	0	0	0	0	0
		DEODORANT	1	3	1	0	0	0	0	0
		FISH OIL	0	0	0	0	0	0	0	0
Trial 7 5 March 2017	AM	CONTROL	2	2	2	0	0	0	0	0
		PREDATOR BAIT	3	154	3	2	2	1	0	0
		COLOGNE	1	1	1	0	0	0	0	0
		WEASEL LURE	3	75	3	2	1	1	0	0
	PM	CONTROL	0	0	0	0	0	0	0	0
		DEODORANT	1	5	1	0	0	0	0	0
		FISH OIL	1	248	1	1	0	1	0	0
		CATNIP	2	5	2	0	0	0	0	0
		WEASEL LURE*	1	2	1	0	0	0	0	1
Trial 8 11 March 2017	AM	CONTROL	0	0	0	0	0	0	0	0
		DEODORANT	1	2	1	0	0	0	0	0
		CATNIP	1	1	1	0	0	0	0	0
		COLOGNE	0	0	0	0	0	0	0	0
	PM	CONTROL	1	2	1	0	0	0	0	0
		PREDATOR BAIT	5	128	5	3	2	0	0	0
		FISH OIL	7	98	7	5	2	0	0	0
		WEASEL LURE	6	41	6	4	1	1	0	0
Trial 9 19 March 2017	AM	CONTROL	3	3	3	0	0	0	0	0
		PREDATOR BAIT	2	30	2	1	1	0	0	0
		DEODORANT	5	5	5	0	0	0	0	0
		COLOGNE	1	1	1	0	0	0	0	0
	PM	CONTROL	0	0	1	0	0	0	0	0
		FISH OIL	2	22	2	0	0	0	0	0
		CATNIP	1	1	1	0	0	0	0	0
		WEASEL LURE	1	1	1	0	0	0	0	0

**Denotes return to previous scent location when block not present during observation period*

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