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Feral cats and the *fitoaty*: first population assessment of the black forest cat in Madagascar's rainforests

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Despite exceptionally high levels of biodiversity and endemism found in Madagascar, much of its wildlife remains little studied, particularly the carnivore community. The recently described, little-known black forest cat (locally known as "*fitoaty*") is believed to be restricted to NE Madagascar and has been investigated only through village surveys and anecdotal accounts. From 2008 to 2012, we photographically sampled 7 forest sites with varying degrees of degradation and fragmentation across Makira Natural Park with the goals of: 1) estimating landscape occupancy for *fitoaty* (*Felis* spp.), 2) identifying variables influencing *fitoaty* occupancy, and 3) comparing *fitoaty* and feral cat (*Felis* spp.) occupancy across the landscape. We observed higher occupancy for *fitoaty*, minimal co-occurrence between *fitoaty* and feral cats (n = 2 sites), and strong divergence in habitat use. We provide the 1st assessment of *fitoaty* morphology, including comparisons with anecdotal reports, and the 1st population assessment of Madagascar's exotic cat community with insights into factors associated with carnivore population trends in Madagascar. We suggest the described *fitoaty* is a phenotypically different form of the feral cat, but additional research is needed. Targeted management plans are needed to diminish the spread and potential negative effects of invasive cats across this important biologically diverse ecoregion.

Key words: camera trapping, carnivore community, exotic predator, invasive species, Makira Natural Park, Masoala National Park, occupancy, population modeling

Madagascar represents one of the world's top biodiversity hotspots with high levels of endemism (Mittermeier et al. 1998; Myers et al. 2000). Madagascar's diverse, endemic wildlife faces threats from numerous anthropogenic pressures including intense forest loss, human encroachment, exotic species, and poaching (Brooks et al. 2002; Harper et al. 2007; Golden 2009; Irwin et al. 2010; Gerber et al. 2012a; Goodman 2012; Farris et al. 2015a). As a result, Madagascar is a global conservation priority (Mittermeier et al. 1998; Myers et al. 2000). Despite exceptionally high levels of biodiversity and endemism found in Madagascar, much of its wildlife remains poorly studied. In particular, Malagasy carnivores are perhaps the least studied and most threatened carnivores in the world (Brooke et al. 2014). The limited research that is available has drawn attention to the influx of exotic carnivores in eastern rainforest habitat, including their negative interactions with native carnivores and co-occurring wildlife (Gerber et al. 2010; Gerber et al. 2012a; Farris et al. 2014, 2015a, 2015b; Farris et al. in press). However, our understanding of exotic carnivores' behavior and their role within rainforest ecosystems remains limited.

Among exotic carnivores in Madagascar, feral or wild cats (*Felis* spp.; hereafter "feral cat") pose a significant threat due to their adaptability, their efficient, generalist hunting behavior, and their elusive behavior (Bonnaud et al. 2011; Campbell et al. 2011; Medina et al. 2011). Feral cats have been shown to negatively affect native wildlife in Madagascar (Barcala 2009); however, reports or accounts quantifying the direct or indirect impacts of cats (domestic, feral, or wild) are scarce (Gerber et al. 2012a; Farris et al. 2014, 2015a, 2015b; Farris et al. in press). Further, no published work is available to fully describe the behavior, morphology, or diet of feral cats occupying forest habitat across Madagascar.

To date, both domestic (i.e., those belonging to a local household and largely constrained to villages) and feral (i.e., those without owners that forage on their own within or nearby forested areas) cats *Felis* spp. have been documented in numerous ecosystems throughout Madagascar (Goodman 2012).

Madagascar's feral cats have been described by Goodman (2012) and Brockman et al. (2008) as being larger than domestic cats with a tabby fur pattern and a tail usually marked with dark rings and a black tip (hereafter referred to as feral cats). However, in addition to these domestic, feral, and/or wild cats, anecdotal accounts from local villagers across northeastern Madagascar describe a phenotypically different wild cat that is only found within rainforest habitat and is described as black in pelage and larger in body size. In fact, this wild black cat is so widely known among native villages across the Masoala peninsula of Madagascar that it has received the name "*fitoaty*," meaning 7 livers (Borgerson 2013). Borgerson (2013) provided the 1st survey of local knowledge and description of the *fitoaty*; however, our recent photographic surveys presented here were conducted across the Masoala-Makira landscape (Farris and Kelly 2011; Farris et al. 2012, 2014, 2015b) and provide the first photographic data of the presence of feral cats and the recently described *fitoaty* across this region, including photographic captures that allow for ecological and morphological comparison of both cats across eastern rainforest habitat.

The tabby feral cat described by Goodman (2012) and Brockman et al. (2008) has been found in multiple forest types throughout Madagascar, but the only accounts of the black *fitoaty*, to our knowledge, come from the northeastern rainforests (Borgerson 2013; Farris et al. 2015a, 2015b). Before this study, the occurrence of the *fitoaty* had only been noted through anecdotal observations made by Borgerson (2013). In our discussions with local people and local researchers across this region (Masoala-Makira region; Betsimisaraka), locals describe the *fitoaty* to be larger in size and weight than the largest of the extant, native carnivores, the fossa (*Cryptoprocta ferox*), and sometimes refer to it as the "black fossa." To date, no genetic studies on cats, wild or domestic, exist for Madagascar, thus the taxonomic classification for these various members of Felidae is lacking. Despite the lack of genetic confirmation of taxonomic status, and the fact that the feral and *fitoaty* cats likely may be wild or semi-wild forms of domestic cats in Madagascar, the impacts of such exotic predators have been shown to be a serious threat to native wildlife (Farris et al. 2014, 2015a, 2015c) and should be further investigated to improve our management efforts for native species.

We estimated site occupancy of these felids and determined the habitat and landscape variables influencing their presence in the northeastern rainforests, to serve as a baseline for future studies for Madagascar felid populations. Further, we compare these findings with the occupancy of tabby feral cats described by Goodman (2012) and Brockman et al. (2008), captured within the same survey locations. Our objectives were to: 1) estimate the single-season, single-species occupancy and detection of *fitoaty* and feral cats across the landscape; 2) identify important camera station-level habitat, landscape, and co-occurring species explanatory variables for occupancy and detection; 3) compare occupancy model results between the *fitoaty* and feral cats; and 4) compare the *fitoaty* morphology with feral cat morphology and with anecdotal reports of *fitoaty* from Borgerson (2013).

Methods

Study site.—This work was part of a larger study to investigate the influences of anthropogenic pressure (degradation, fragmentation, human encroachment, exotic species, and poaching) on Madagascar's carnivores and lemurs across the Masoala-Makira landscape (Farris et al. 2014). The Masoala-Makira landscape (Fig. 1), which consists of the Makira Natural Park (372,470 ha of protected area and 351,037 ha of community management zone) and Masoala National Park (240,000 ha), represents Madagascar's largest protected area complex and is estimated to contain the highest levels of biodiversity in Madagascar (Holmes 2007).

Photographic sampling.—From 2008 to 2012, we surveyed 7 forest sites (Fig. 1) along a gradient from least (S01) to most (S02) degraded, including repeated surveys of 2 sites (S02 and S05) for a total of 13 surveys. We conducted repeat surveys to investigate multiseason population trends in native and exotic carnivores. To photographically sample wildlife at each site, we established a camera grid consisting of 18–25 camera stations spaced approximately 500 m apart. Each camera station consisted of a pair of remote-sensing camera traps (Reconyx PC85 and HC500, Holmen, Wisconsin; Moultrie D50 and D55, Calera, Alabama; Cuddeback Infra Red, Green Bay, Wisconsin; DeerCam DC300) positioned on each side of existing human (0.5–2.0 m wide) or game (< 0.5 m wide) trails. We placed cameras approximately 20–30 cm off the ground, slightly offset to prevent mutual flash, and were functional for an average of 67 days per survey. We used no bait or lure to attract wildlife to individual camera stations. We used noninvasive methods to survey wildlife which followed the guidelines of the American Society of Mammalogists (Sikes et al. 2011) and, as a result, we did not require permission from an institutional animal care and use committee.

Station-level habitat and landscape sampling.—We established three, 50-m transects starting at the camera station and running in the directions of 0°, 120°, and 240°. Along each transect, we estimated canopy height and cover at 10-m intervals and tree density and basal area at 25 and 50 m using the point quarter method following Davis et al. (2011). At 20 and 40 m, we established a 20-m long transect running perpendicular to the 50-m transect to estimate understory cover at multiple levels by placing a 2-m long pole at every odd meter and recording the forest floor cover and whether vegetation was touching the pole at heights of 0–0.5, 0.5–1.0, and 1.0–2.0 m.

To measure landscape variables, we used Landsat satellite imagery (2004, 2006, and 2009) to classify habitat cover (rainforest, degraded forest, matrix, and cultivated area) in Erdas Imagine (see Farris et al. 2014 for more detail on GIS layers and landscape analyses). We placed a 250 m buffer (totaling 500 m diameter) around each camera station and used the classified imagery to calculate metrics of fragmentation for each camera grid in program FragStats (McGarigal et al. 2012). Finally, using the satellite imagery, we provided the average distance of camera stations within each grid to the nearest village and to the nearest forest edge. These station-level habitat

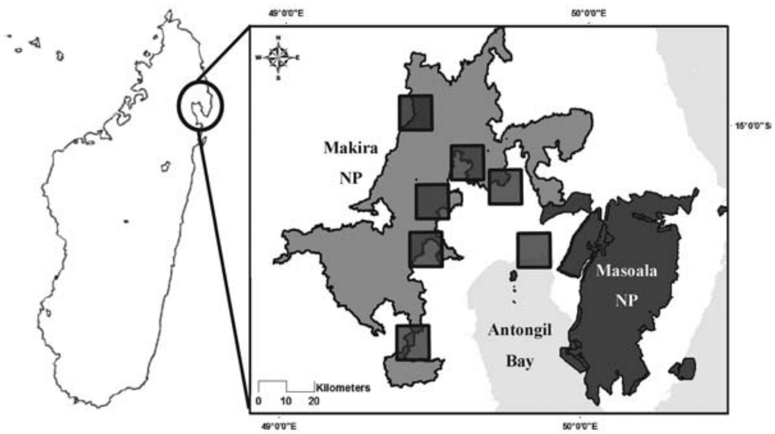

Fig. 1.—Map of the Masoala-Makira landscape in NE Madagascar, where photographic surveys were conducted on the carnivore community from 2008 to 2012 (S01 in 2008; S02 in 2013; S03 in 2009; S04 in 2011; S05 in 2012; S06 in 2009; and S07 in 2010). Shaded boxes represent the regions of the landscape where our 7 survey sites were located. Use of bushmeat survey data from previous work at these sites prevented us from labeling the precise locations of sites.

and landscape variables were used as covariates to explain patterns in feral cat and *fitoaty*'s occupancy across the landscape.

Cat and co-occurring species activity.—For carnivores, birds, and small mammals, we provided a measure of activity across sites by calculating trap success (total number of capture events divided by the number of trap nights, multiplied by 100; a trap night is a 24-h period in which at least one camera was functioning properly). We defined a "capture event" as all photographs of a distinct individual of a particular species within a 30-min time period (Di Bitetti et al. 2006). To estimate the occupancy of feral cats and *fitoaty* and assess the impacts of station-level habitat, landscape, and co-occurring species variables on their occupancy, we created capture histories (collapsed into 6-day increments to improve model convergence) to determine their presence (1) or absence (0) at each camera station. For sites with multiple sampling seasons, we used the most recent survey conducted as these surveys had higher photographic captures of both cats. We used program PRESENCE (Hines 2006) to estimate cat occupancy and detection while accounting for imperfect detection (Bailey et al. 2004). We used the following variables as covariates in our occupancy models: distance to edge (km), distance to village (km), bird trap success, small mammal trap success, average canopy cover, tree density, total understory, trail width (m), and human trap success. We used the *Z*-score method to normalize all covariate values for our occupancy models. We ranked models using Akaike's Information Criterion (AIC) and considered models with a ΔAIC of ≤ 2 as competing model (Burnham and Anderson 2002). We ensured model convergence and used Goodness-of-Fit (GOF) tests to estimate c-hat and apply c-hat corrections where necessary. Any model having a c-hat value > 3.0 was considered to be overdispersion and was not used.

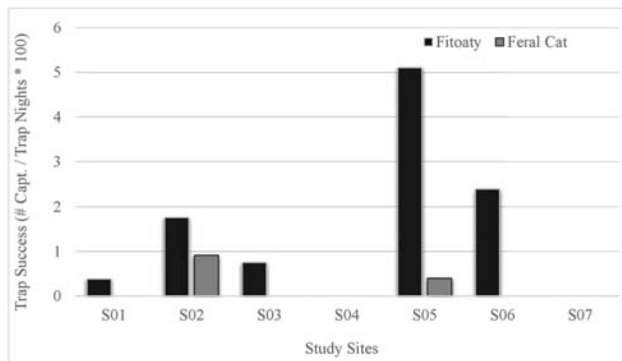

Fig. 2.—Trap success for the *fitoaty* (black) and feral cat *Felis* spp. (gray) across the 7 study sites (S01–S07) listed from least to most degraded. Trap success is the total number of species capture events divided by the total trap nights per study site. Photographic sampling was conducted at 7 sites across the Masoala-Makira landscape from 2008 to 2012.

Results

Our photographic surveys from 2008 to 2012 provided a total of 14,045 trap nights across 7 study sites, resulting in 2,991 captures of carnivores (33% native and 67% exotic—Farris et al. 2014). Out of 159 felid photo captures, approximately 87% were captures of the large, black *fitoaty*. The *fitoaty* was detected at 5 sites while the tabby feral cat was detected at only 2 sites (Fig. 2). We observed little geographic overlap between *fitoaty* and feral cats with co-occurrence at only 2 sites (S02 and S05; Fig. 2). The *fitoaty* had a higher probability of occupancy across the landscape ($\psi = 0.36 \pm SE\ 0.06$) than the feral cat ($\psi = 0.22 \pm SE\ 0.14$; Table 1), although confidence intervals overlapped.

We found *fitoaty* occupancy was best explained (positively) by small mammal trap success ($\beta = 0.41 \pm SE = 0.22$; Fig. 3a) and detection was best explained (positively) by bird trap success ($\beta = 0.42 \pm SE = 0.18$; Table 1). In contrast, feral cat occupancy was best explained (negatively) by small mammal and bird trap success ($\beta = -2.03 \pm SE = 1.26$ and $-1.34 \pm SE = 1.09$, respectively; Fig. 3a), while detection was negatively related to human trap success ($\beta = -6.73\ SE = \pm\ 6.31$; Table 1). Though distance from village was not present in top-ranking models (ΔAIC < 2.0; Table 1), we found noticeable patterns in the

Table 1.—Top-ranking (ΔAIC < 2.0), single-season, single-species occupancy models, including probability of occupancy (Ψ, *SE*) and detection (*P*, *SE*), for *fitoaty* and feral cat *Felis* spp. across the Masoala-Makira landscape. Sampling occurred from 2008 to 2012 across 7 study sites varying in levels of habitat degradation. s.mammal = small mammal trap success; bird = all bird species trap success; village = distance to nearest village; edge = distance to closest edge of the forest; trail = width of the trail in meters; human = local, nonresearcher trap success.

Cat	Model	AIC	ΔAIC	AIC weight	*k*	Ψ (*SE*)	*P* (*SE*)
Fitoaty	Ψ (s.mammal), *P*(bird)	595.74	0.00	0.37	4	0.37 (0.07)	0.15 (0.02)
	Ψ (.), *P*(bird)	597.72	0.85	0.14	3	0.37 (0.05)	0.15 (0.02)
	Ψ (s.mammal, village), *P*(bird)	597.74	2.00	0.14	5	0.37 (0.08)	0.15 (0.02)
	Ψ (village), *P*(bird)	599.68	2.94	0.08	4	0.37 (0.07)	0.15 (0.02)
	Ψ (edge), *P*(bird)	598.79	3.05	0.08	4	0.36 (0.07)	0.15 (0.02)
	Ψ (trail), *P*(bird)	598.96	3.22	0.07	4	0.37 (0.05)	0.15 (0.02)
	Ψ (human), *P*(bird)	599.71	3.97	0.05	4	0.37 (0.06)	0.15 (0.02)
Feral cat	Ψ (s.mammal,bird), *P*(human)	132.04	0.00	0.50	5	0.23 (0.14)	0.03 (0.02)
	Ψ (s.mammal), *P*(human)	132.89	0.85	0.32	4	0.23 (0.13)	0.03 (0.02)
	Ψ (bird), *P*(human)	135.60	3.56	0.08	4	0.21 (0.13)	0.03 (0.02)

spatial distribution of captures between the *fitoaty* and feral cat. Models accounting for distance to village showed that *fitoaty* occupancy was lower closer to villages, while the feral cat occupancy was higher closer to villages (Fig. 3b).

Our visual examination of photographic captures from the same camera station where these cats were captured at similar distances and angles from the cameras suggests the *fitoaty* appears to be larger in body size and has different and distinct morphological traits compared to the feral cat (Figs. 4a and 4b). The *fitoaty* appears to be similar in height to Madagascar's largest native predator, the fossa *C. ferox* (Fig. 5a) and larger than other co-occurring, native carnivores such as the spotted fanaloka *Fossa fossana* (Fig. 5b).

Discussion

We present the 1st photographic evidence of the existence of the recently described *fitoaty* and provide insight into the factors explaining its probability of occupancy across the Masoala-Makira landscape. *Fitoaty* were geographically widespread within the Masoala-Makira landscape and had a higher number of captures in less degraded forest sites than did the feral cat (Fig. 2). This finding concurred with anecdotal information from local people who suggest the *fitoaty* occupies intact rainforest and does not spend time at the forest edge or near villages. However, we also found a high number of captures in our intermediately degraded forest site (S05), which indicated that the *fitoaty* uses a variety of forest types, as has been observed for feral and/or wild cats, throughout Madagascar and in similar habitats worldwide (Brockman et al. 2008; Campbell et al. 2011; Gerber et al. 2012a; Spotte 2014; Farris et al. 2015b).

Interestingly, while the feral cat was only captured near forest edges and near villages, it was not detected within our most degraded and/or fragmented forest sites (S06 and S07). The lack of feral cat captures in degraded/fragmented forest sites may result from locals hunting these cats as consumption rates of carnivores across this region is high, including consumption rates of cats *Felis* spp.

Our findings regarding the relationship between small mammal and bird trap success and feral cat occupancy highlight the importance of potential prey species as a possible explanation

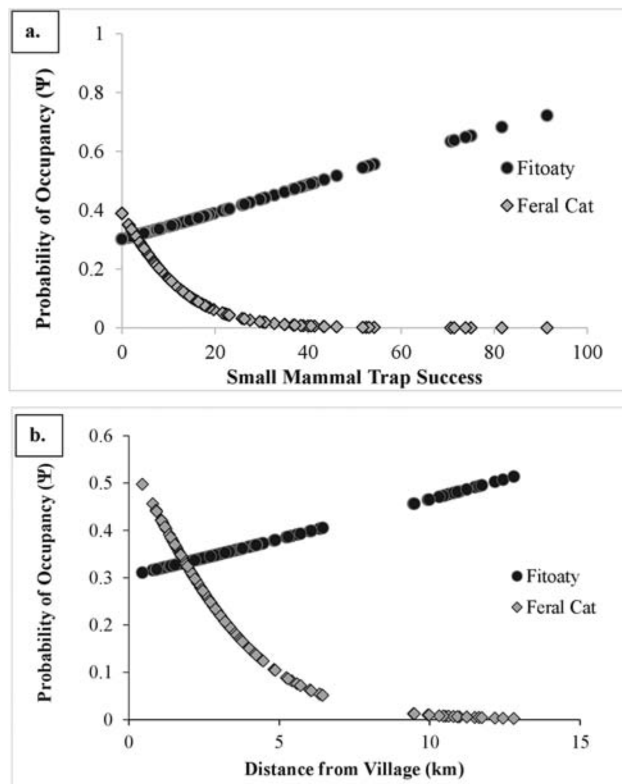

Fig. 3.—Change in the probability of occupancy for *fitoaty* (black) and *Felis* spp. (gray) in response to a) small mammal trap success, and b) distance to village (km). Photographic sampling was conducted across the Masoala-Makira landscape from 2008 to 2012.

for the occupancy trends of cats *Felis* spp. in Madagascar's forests. We do have photographic evidence of *fitoaty* carrying dead native, endemic rodents (implying they actively hunted them) across our study sites (Z. J. Farris and A. Murphy, pers. obs.), but we still have no understanding of the number or the variety of species being killed by cats. The opposite relationship between the *fitoaty* (positive) and the feral cat (negative) in relation to small mammal trap success and distance to village suggests that these 2 cats may fill different niches as indicated by prey resource utilization and/or habitat selection. Care must be taken, however, when evaluating competing models and

Fig. 4.—Visual comparison of body shape and size from photographic captures for both feral cat *Felis* spp. versus *fitoaty* a) at the same camera station for size comparison and b) at different camera stations for comparison of morphometrics. Photographic sampling took place from 2008 to 2012 across the Masoala-Makira landscape.

covariates influencing cat occupancy given the lack of strong support for a single top model and subsequent limited model separation (Arnold 2010). After completing post-hoc model averaging to assess the importance of these variables on the occupancy of both *fitoaty* and feral cats we found the top-ranking variables, primarily small mammals, retained their importance for explaining the occupancy of both cats. We recognize that our results are correlative and the positive associations with small mammals for *fitoaty*, yet negative for feral cats, may simply result from these cats being found in different parts of the study sites where small mammal occurrence is different.

Recent work across this region revealed a strong positive relationship among the bird and small mammal trap rates and the 4 native carnivore species (Farris et al. 2015b). This does raise concern that the prevalence of cats, and their potential relationship with native prey species described herein, may have contributed to the diminishing native carnivore populations documented across this region (Farris et al. 2015b). Our past work has demonstrated that cat activity (calculated as trap success) has a negative effect on spotted fanaloka *F. fossana* occupancy (Farris et al. 2015b), where cats show strong co-occurrence (use same sites more often than predicted by chance) with falanouc *Eupleres goudotii* (Farris et al. 2015c), and cats show strong temporal overlap with multiple native carnivores, indicting the potential for increased interactions and competition. We found cat (feral and *fitoaty* combined) occupancy increased from 0% to 60% from 2008 to 2013 at one of our repeat survey sites (S02) while native carnivores showed strong declines in occupancy during this same time (Z. J. Farris and A. Murphy, pers. obs.). These findings suggest a great need for continued surveys across this region, using a multiseason occupancy framework, to determine changes in occupancy over time and the further assess effects of cats on native wildlife. The photographic surveys that lead to the occupancy results in this study were single-season surveys only (no repeat surveys) and thus the estimates of occupancy for these 2 cats across the landscape could change with multiseason occupancy analyses. Additional, repeat photographic surveys are needed to fully assess how the 2 cats spatially occur across the landscape and to isolate the variables having the greatest influence on their occupancy.

Our on-going work on Madagascar's cat populations (Farris et al. 2014, 2015b, 2015c) has contributed to existing accounts of how invasive cats negatively affect native wildlife across the tropics (Shah 2001; Nogales et al. 2004; Rodríguez et al. 2006; Bonnaud et al. 2011; Medina et al. 2011). Additionally, our findings expand the knowledge of how exotic cats use rainforest habitats and the variables influencing landscape occupancy.

Fig. 5.—Photographic captures of the *fitoaty Felis* spp. at the same camera stations as a) fossa *Cryptoprocta ferox* and b) spotted fanaloka *Fossa fossana* for comparison of body size. We conducted photographic surveys across the Masoala-Makira landscape from 2008 to 2012.

Given the considerably larger body size of both cats compared to Madagascar's smaller, sympatric vontsira carnivores (ring-tail vontsira *Galidia elegans*, broad-stripe vontsira *Galidictis fasciata*, and brown-tail vontsira *Salanoia concolor*), there is a strong potential for competition between cats and these native carnivore populations, including potential for intraguild predation. In addition to the threat posed to terrestrial species, tabby feral cats have been observed killing multiple lemur species in habitats throughout Madagascar (Goodman 2003; Brockman et al. 2008). The 2 sites in our study with the highest number of feral cat and *fitoaty* captures (S02 and S05) host multiple threatened lemur species, including the critically endangered black-and-white and red ruffed lemurs (*Varecia variegata subcincta* and *Varecia rubra*, respectively), the indri (*Indri indri*), and the silky sifaka (*Propithecus candidus*), as well as the endangered white-fronted brown lemur (*Eulemur albifrons*) and the aye-aye (*Daubentonia madagascariensis*) (IUCN 2014).

Our photographic captures do not allow for detailed comparisons of morphometrics; however, captures of these 2 cats and co-occurring native carnivores at the same angles and distances at the same camera stations did allow for visual assessment of overall body size and shape. Photographic captures of the *fitoaty* from our surveys supported the anecdotal accounts and descriptions provided by Borgerson (2013), including accounts of the overall large body size of *fitoaty* compared to the feral cat. The *fitoaty* appeared to have longer legs with the hind legs being highly muscular and larger than the front. The *fitoaty* appeared to have a thinner torso, and a smaller, more defined head than the feral cat. Captures of the black *fitoaty* revealed occasional faint dark stripes, whereas the feral cat always had a light grey/brown pelage with prominent dark stripes. Further, numerous captures of both *fitoaty* and the largest native carnivore, the fossa *C. ferox*, showed a similar body size for both carnivores. Other recent research revealed a negative relationship in occupancy between cats and native carnivores, including a lower occupancy of native carnivores and lemurs in areas with high cat presence (Farris et al. 2014, 2015b; Farris et al. in press). These findings concurred with similar studies investigating the impact of exotic cats on native wildlife worldwide (Medina et al. 2011).

Domestic, feral, and wild cats have been described for Madagascar (Goodman 2012); however, genetic analyses and proper taxonomic placement have yet to be carried out and would improve our understanding of domestic and feral cat varieties in Madagascar. We suspect that the described *fitoaty* is simply a phenotypically different form of the feral cat described by Goodman (2012). However, the divergence in habitat use and/or preference between tabby feral cats and *fitoaty* highlighted by this study requires further investigation to improve our understanding of their ecological impact on these forests.

At this site and others across the Masoala-Makira landscape (Farris et al. 2015a, 2015b) and Ranomafana National Park (Gerber et al. 2012a, 2012b), we have shown the negative effects of *Felis* spp. on multiple native bird, small mammal, lemur, and carnivore species within both degraded and nondegraded forests. Due to the destructive nature of feral cats on native wildlife communities, we suggest a widespread capture–euthanize program for exotic cats be considered, particularly in areas protecting endangered or critically endangered species. These capture–euthanize programs additionally could supply important data on the genetics, parasite and pathogen transfer, diet, and morphology, of these exotic predators. Feral cat capture–euthanize programs have had mixed results, but numerous efforts have proven successful (Nogales et al. 2004).

Our findings provided important insight into how exotic cats demonstrated divergence in their use and/or selection of forest habitat across the Masoala-Makira landscape. Thus, any capture–euthanize programs would require flexibility in targeting both types of cats in executing management or control programs. *Felis* spp. increasing distribution, specialization, and potential wide-ranging negative effects on tropical forests highlight the need for action by conservationists and managers worldwide.

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