Salanoia concolor: The vanishing brown-tailed vontsira, a short review of research and conservation needs across the Parc Naturel Makira

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Abstract

The brown-tailed vontsira (*Salanoia concolor*) is a member of the Malagasy endemic family Eupleridae that is listed on the IUCN Red List as Vulnerable. This species is restricted to the humid lowland moist evergreen forests of eastern Madagascar. Despite over a century of taxonomic recognition, the species remains among the island's least-studied carnivorans. Herein, we present the results of a six-year (2008-2013) camera trap monitoring effort across the Parc Naturel Makira, establishing the foundational, systematic baseline for the species' ecology and conservation status through landscape-scale surveys in the protected area. Results confirmed a highly restricted distribution; in a survey effort of 16,431 trap nights (110,096 total animal captures) there were only 62 total detections of *S. concolor* and they were recorded only at two of the seven surveyed sites, with 57 (92%) at a single site - Anjanaharibe. Occupancy modeling indicates that *S. concolor* is highly sensitive to anthropogenic pressure, exhibiting a significant negative association with human activity (β = -36.75 ± 17.44) and a preference for non-degraded forest. Multi-season analysis revealed a substantial reduction in occupancy at Anjanaharibe, decreasing from ψ = 0.87 to ψ = 0.16 over five years. This trend is characterized by high local extirpation rates of ε = 0.49 (± 0.13) and the identification of spatial avoidance of domestic dogs (*Canis familiaris*) present in the forest. These findings indicate a significant contraction of the species' remaining population, supporting the need for an urgent IUCN reassessment of its conservation statute and targeted management to mitigate the dual pressures of habitat degradation and invasive predators.

Keywords: *Salanoia,* Makira, Anjanaharibe, long-term censuses, population decline, dogs

Résumé détaillé

La Salanoia (*Salanoia concolor*) appartient à la famille des Eupleridae, endémique de Madagascar, et figure sur la Liste rouge de l'UICN comme espèce Vulnérable. Cette espèce est restreinte dans les forêts humides sempervirentes de basse altitude de l'Est de Madagascar. Bien qu'elle soit reconnue sur le plan taxonomique depuis plus d'un siècle, elle reste l'un des Carnivora les moins étudiés de l'île. Les résultats d'un programme de suivi par pièges photographiques, mené pendant six ans (2008-2013) dans le Parc Naturel Makira, sont présentés ici. Ce programme a permis d'établir une base de référence fondamentale et systématique concernant l'écologie et l'état de conservation de l'espèce, grâce à des relevés à l'échelle du paysage réalisés dans l'aire protégée.

Les résultats confirment que l'aire de répartition de l'espèce est très restreinte. En effet, sur un effort de suivi, totalisant 16 431 nuits de piégeage (pour un total de 110 096 captures de photos d'animaux), seules 62 détections de *S. concolor* ont été enregistrées. Ces observations ont eu lieu dans deux des sept étudiés, la quasi-totalité d'entre elles (57 détections, soit 92 %) provenant d'un seul site, Anjanaharibe. La modélisation de l'occupation de l'espèce indique que *S. concolor* est très sensible à la pression anthropique. Elle présente une corrélation négative significative avec l'activité humaine (β = -36,75 ± 17,44), ainsi qu'une préférence pour les forêts non dégradées. Une analyse multi-saisonnière révèle une réduction substantielle de son occupation à Anjanaharibe, qui est passée de ψ = 0,87 à ψ = 0,16 en cinq ans. Cette tendance se caractérise par un taux d'extirpation locale élevés (ε = 0,49 (± 0,13), ainsi que par la mise en évidence d'un comportement d'évitement spatial envers les chiens domestiques (*Canis familiaris*) présents dans la forêt. Ces résultats témoignent d'une nette réduction de la population

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restante de l'espèce. Un tel déclin justifie une réévaluation urgente de son statut de conservation par l'UICN, ainsi que la mise en place d'une gestion ciblée visant à atténuer la double pression exercée par la dégradation de l'habitat et les prédateurs introduits.

Mots clés : *Salanoia*, Makira, Anjanaharibe, recensements à long terme, déclin des populations, chiens

Introduction

Background and natural history

The brown-tailed vontsira (*Salanoia concolor*), is one of two members within the genus *Salanoia*, alongside the recently described Durrell's vontsira (*S. durrelli*) known only from the Lac Alaotra region (Durbin *et al.*, 2010) and subsequently shown to be a synonym of *S. concolor* (Veron *et al.*, 2017). Both belong to the endemic Malagasy carnivore family Eupleridae, a monophyletic clade encompassing all of Madagascar's native carnivores (Yoder *et al.*, 2003). Within this unique family, *Salanoia* remains one of the least known and is classified as Vulnerable on the IUCN Red List. Its distribution is limited to the humid lowland moist evergreen forests of central and northeastern Madagascar, including protected areas such as Masoala, Makira, Zahamena, Betampona, and Mananara-Nord (Goodman, 2013). Most confirmed records occur below 650 m below sea-level, highlighting the species' reliance on lowland forest habitats, which by proxy of being also favored by humans renders the species particularly susceptible to anthropogenic pressures, most notably habitat fragmentation and deforestation (Wampole *et al.*, 2021; Farris & Murphy, 2022).

Morphologically, *S. concolor* is a small, slender carnivore with a total body length ranging from 470 to 580 mm and a body mass between 600 and 780 g (Figure 1). Despite this species being named over a century ago, we still lack a fundamental understanding of its life history, including reproductive biology, population density, and social structure (Goodman, 2012; Wampole *et al.*, 2021). Available studies describe the brown-tailed vontsira as primarily diurnal, with peak activity in the early morning. As an opportunistic generalist, *S. concolor*'s diet consists mainly of insects, invertebrates, and amphibians (Goodman, 2012; Farris *et al.*, 2015a). Camera trap surveys have observed individuals resting in burrows or hollow trees and occasionally moving in pairs, suggesting potential social behaviors that we have yet to fully understand, and which may mirror those of *Galidia elegans* (Goodman, 2012; Hawkins, 2016).

The population status of *S. concolor* is increasingly uncertain and challenging due to ongoing habitat loss, hunting by humans and dogs, and competition with introduced carnivoran species such as domestic dogs (*Canis familiaris*), cats (*Felis catus*), and the small Indian civet (*Viverricula indica*). Even within protected areas like the Parc National de Masoala, illegal logging, slash-and-burn (*tavy*) agriculture, and artisanal mining continue to contribute to forest degradation, eroding suitable habitat (Farris *et al.*, 2015b, 2016; Hawkins, 2016; Wampole *et al.*, 2021). The scarcity of the genus in most recent records associated with carnivoran surveys, particularly with camera traps, raises concern that the species may be in rapid decline, which may warrant a reassessment



Figure 1. Camera trap images of brown-tailed vontsira (*Salanoia concolor*) captured from the Parc Naturel Makira between 2008 and 2013, specifically at the Anjanaharibe conservation site. **A**) Two adults captured January 2011 and **B**) a single adult captured in November 2008.

of their IUCN conservation status. As one of Madagascar's rarest and understudied carnivores, *S. concolor* represents a priority for further ecological research and conservation action aimed at ensuring the survival of the island's endemic fauna (Goodman, 2012; Hawkins, 2016; Farris & Murphy, 2022).

Review of *Salanoia* research in the Parc Naturel Makira

Camera trap surveys

Starting in 2008, the first camera trap surveys were conducted in the Parc Naturel Makira (hereafter Makira) by Wildlife Conservation Society and researchers from Virginia Tech, USA. These surveys were conducted from 2008 to 2013 across seven different sites bordering and within the Makira (Figure 2) (Farris *et al*., 2015b). Two of the sites (Anjanaharibe at 15.19984°S, 49.62074°E and Mangabe at 15.31348°S, 49.50233°E) were surveyed multiple times over this six year period. Across the seven sites, the number of operating camera stations ranged from 18 to 25 with surveys averaging 22 cameras per site. Total survey effort spanned across these sites for a total of 824 days, resulting in a total of 16,431 trap nights (i.e. a trap night is a camera recording non-stop for a 24 hour period). These camera trap surveys produced a total of 110,096 photographic captures of humans and wildlife. Of these captures, a total of 62 unique photographic captures of *Salanoia* were recorded over this six-year period. The vast majority (n = 57 or 92%) resulted from repeat surveys of the Anjanaharibe site, while the remaining photos (n = 5 or 8%) came from a degraded area bordering Makira (Sahavary at 15.29275493°S, 49.7677064°E). No observations of *Salanoia* were made from any of the other surveyed sites, despite extensive sessions over large spatial areas (Farris *et al*., 2015b).

Walking transect surveys

Over the same six-year period described above from 2008 to 2013, our research teams carried our walking transect surveys (primarily for diurnal and nocturnal lemur species) throughout six of these seven camera trap sites. These surveys included three transects varying between 1.0 and 2.0 km in length and established in each of the six sites across Makira,

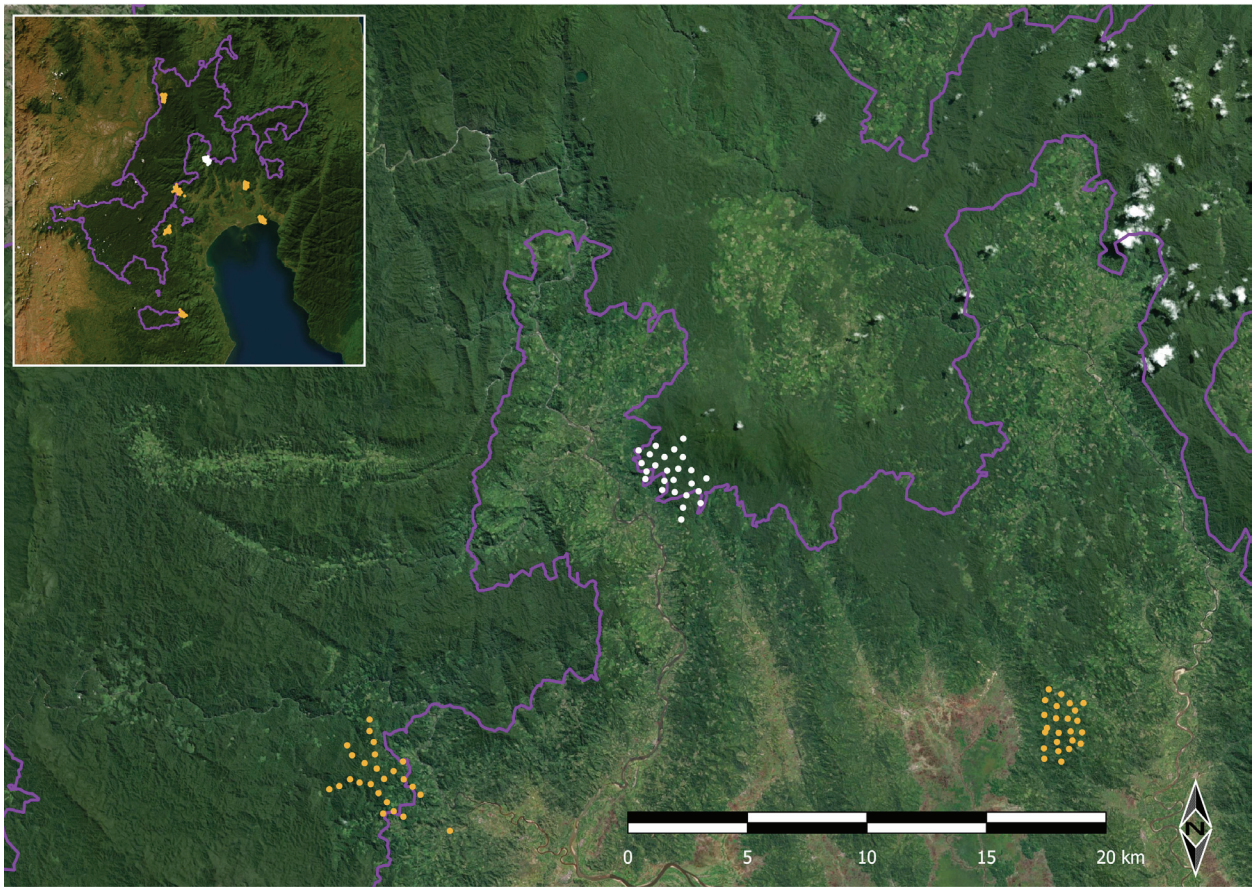

Figure 2. Map of The Parc Naturel Makira (insert in the top left) with boundary (purple line) and locations of the seven camera trap study sites. Larger map shows forest cover and location of Anjanaharibe site with 24 camera stations (white dots), which was the subject of six-year multi-season, repeat surveys. Map also includes location of Sahavary camera stations (bottom, right brown dots) and Mangabe camera stations (bottom, left brown dots).

totaling 27 individual transects (including repeat surveys of Anjanaharibe and Mangabe). These surveys resulted in a total of 420 individual surveys over this six-year period, totaling 823 km traveled (Murphy *et al.*, 2016). Throughout the six-year survey period, no observation was made of *Salanoia concolor* along the transects.

Occupancy analyses and results

Using the camera trap data described above, our research team estimated occupancy parameters for all native and exotic carnivorans using multiple occupancy modeling approaches. Occupancy (ψ) is defined as the probability of a species being present at a sampling site during the study period, where 0 represents absence and 1 is present at all sites. These analyses treat occupancy as the proportion of the spatial landscape occupied by the target species, while accounting for imperfect detection (*p*) (MacKenzie *et al.*, 2002). Using all camera trap data for *Salanoia concolor*, we estimated single-season (single year or survey period), single-species occupancy, multi-season (multiple surveys across years) occupancy, and two-species occupancy. Results for each modeling approach are presented below.

Single-season, single-species

We organized all surveys across the seven sites into three categories: landscape (all sites combined), non-degraded forest (contiguous sites with little to no disturbance or non-native species), and degraded forest sites (fragmented, disturbed sites with high invasive presence). Our landscape analyses revealed *Salanoia* has a limited distribution across Makira with a landscape estimate of 0.36 (± 0.14 SE). This estimate was similar to other rare native euplerid carnivorans (*Eupleres goudotii* and *Galidictis fasciata*) (Ross *et al.*, 2024). Top ranking landscape models revealed that human trap success (i.e. relative activity or capture rate of people) was the most important variable influencing the spatial distribution of *Salanoia* across all sites (Farris *et al.*, 2015b). We observed a strong negative relationship with human activity (β = -36.75 ± 17.44) and *Salanoia* spatial distribution (Figure 3). Meanwhile, tree density influenced our ability to detect or photographically capture *Salanoia* across all surveys (β = 1.43 ± 0.47) (Farris *et al.*, 2015b). Average tree density per ha at sites where *S. concolor* was captured was 3492 (Anjanaharibe) and 2954 (Sahavary). This compares with the most degraded and fragmented site of Vinanibe (4103 trees/ha) where small sapling trees were abundant and the least degraded, fragmented

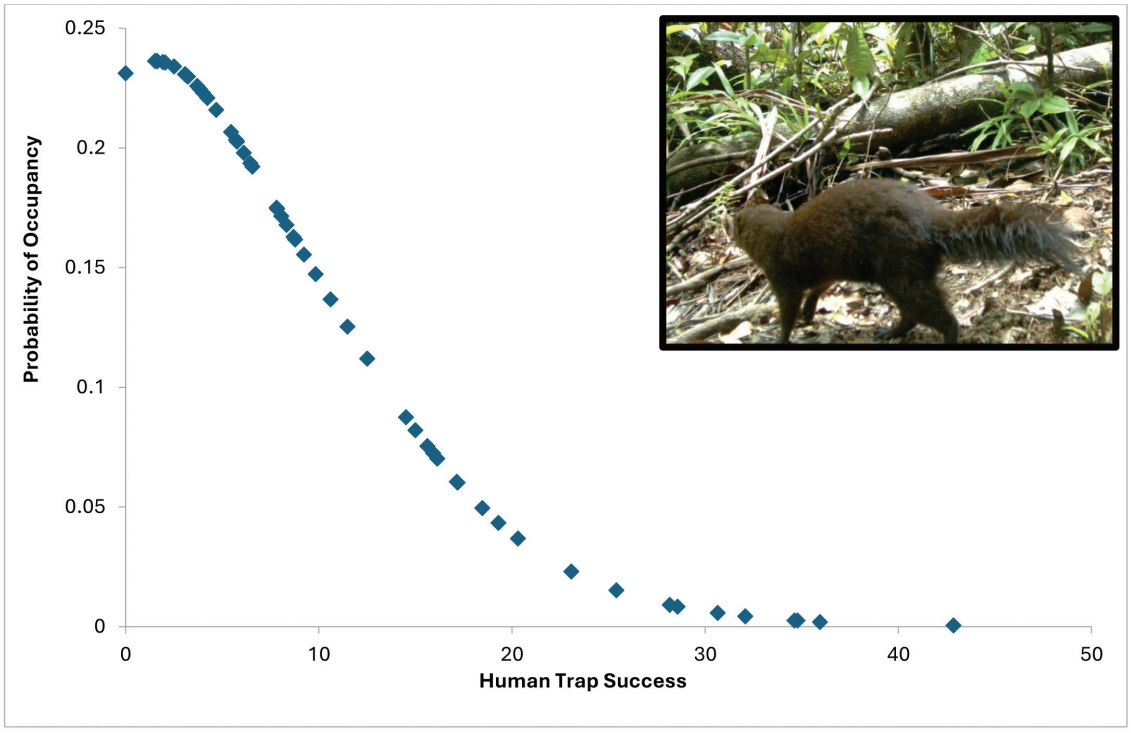

Figure 3. Single-season, single-species occupancy results demonstrating strong negative relationship with *Salanoia concolor* probability of occupancy (y-axis) in relation to human camera trap success (relative activity, x-axis). Data for this model resulted from landscape wide surveys at seven sites across the Parc Naturel Makira, 2008-2013.

site of Soavera (1223 trees/ha) where large, old-growth trees were common.

Across the non-degraded forest sites, we only had a single site, Anjanaharibe (AJB), having *Salanoia* captures. Since this site was re-surveyed across all trapping years, we used the surveys of this site that had the highest number of captures (AJB 2011, n = 21 captures), which provided an estimate of *Salanoia* occupancy of 0.41 (± 0.22 SE). Top-ranking models also revealed a similar relationship with human camera trap success and *Salanoia* spatial occurrence, though not nearly as strong as the landscape model (β = -1.52 ± 1.24).

Across degraded forest sites, we used data from the Sahavary, to estimate occupancy. This single survey produced only five unique camera-trap captures. Estimates of occupancy for degraded sites was much lower and had much more variability compared to non-degraded sites with an estimate of 0.14 (± 0.12). Top-ranking models revealed a positive relationship with zebu cattle (β = 1.05 ± 0.73), highlighting their shared space use and likely residual refuge in marginal landscapes across the Sahavary area.

Multi-season, single-species

Repeat surveys of the Anjanaharibe site started in 2008 and ended in 2013 (Farris *et al*., 2017). The planned 2009 survey was canceled due to political instability on Madagascar. Otherwise, we surveyed this site between late August and early November each year to maintain consistency. Each survey consisted of two cameras at each station with 20-24 stations per survey/year. Each survey ranged from 55 to 72 days with an average of 65 days (± 10). The area surveyed was approximately 15 km^2 (Figure 4). We estimated multi-season, single-species occupancy which provides individual estimates of occupancy for each year/season, as well as estimates of local extirpation and colonization across the site (Farris *et al*., 2017).

Model results revealed strong decreases in occupancy probabilities from 2008 (Ψ = 0.87) to 2013 (Ψ = 0.16), resulting in an estimate of local extirpation (ε) of 0.49 (± 0.13) (Figures 4 & 5). Probabilities of new site colonization by *Salanoia* were exceptionally low (γ = 0.03). The most common variable influencing *Salanoia* occupancy in the context of this time frame was distance to forest edge. *Salanoia* demonstrated a strong positive relationship with edge habitat while limiting activity in areas deeper into the forest of Anjanaharibe. This relationship was consistent for the last five years of surveys even as population trends continued to decrease (Figure 5). This use of edge habitat likely exists at Anjanaharibe due to the low probability of human activity and use across this site. This site is managed and human activity was the second lowest in human trap success, where site Soavera (least degraded and fragmented of all sites) had the lowest human activity.

Almost all native, co-occurring carnivorans showed similar decreasing trends across the Anjanaharibe site from 2008-2013, while non-native (exotic) carnivorans (namely free-roaming *Felis*) showed increases (Figure 6). Changes from initial occupancy in 2008 (dash line) to final occupancy in 2013 (circle) are clearly evident for small-bodied native carnivorans, especially *Galidictis fasciata* and *S*. *concolor*. Their distributional relationship with respect to the forest edge reveals niche divergent relationships and the complexity associated with managing these species and their habitat. We also plot in Figure 7 the probability of extirpation from the Anjanaharibe and similar sites as a function of distance to edge. *Galidictis* avoids edge and their probability of extirpation in considerably higher near forest edge. However, *Salanoia* has much higher probability of extirpation from areas far from edge in core forests. These results demonstrate niche divergence and habitat use for these two species across this region and it further highlights the complexity involved in conserving and managing these co-occurring euplerids across their range. Keeping both species from local extirpation requires protecting and expanding both forms of habitat (edge and core), as well as access to required food, water, and cover for both rare, secretive euplerids.

Two-species occupancy

We used two-species occupancy to investigate co-occurrence between native and non-native carnivorans across the Parc Naturel Makira (Farris *et al*., 2016, 2020). These models predict the probability of the native species occurring at a site where a non-native carnivoran may co-occur. The models provide a measure of species interaction referred to as a species interaction factor (SIF). An SIF estimate of 1.0 reveals no spatial relationship between the two species, whereas an SIF > 1.0 shows convergence and < 1.0 shows spatial avoidance. Given the increasing presence of non-native carnivorans, namely *Canis familiaris, Felis catus,* and *Viverricula*

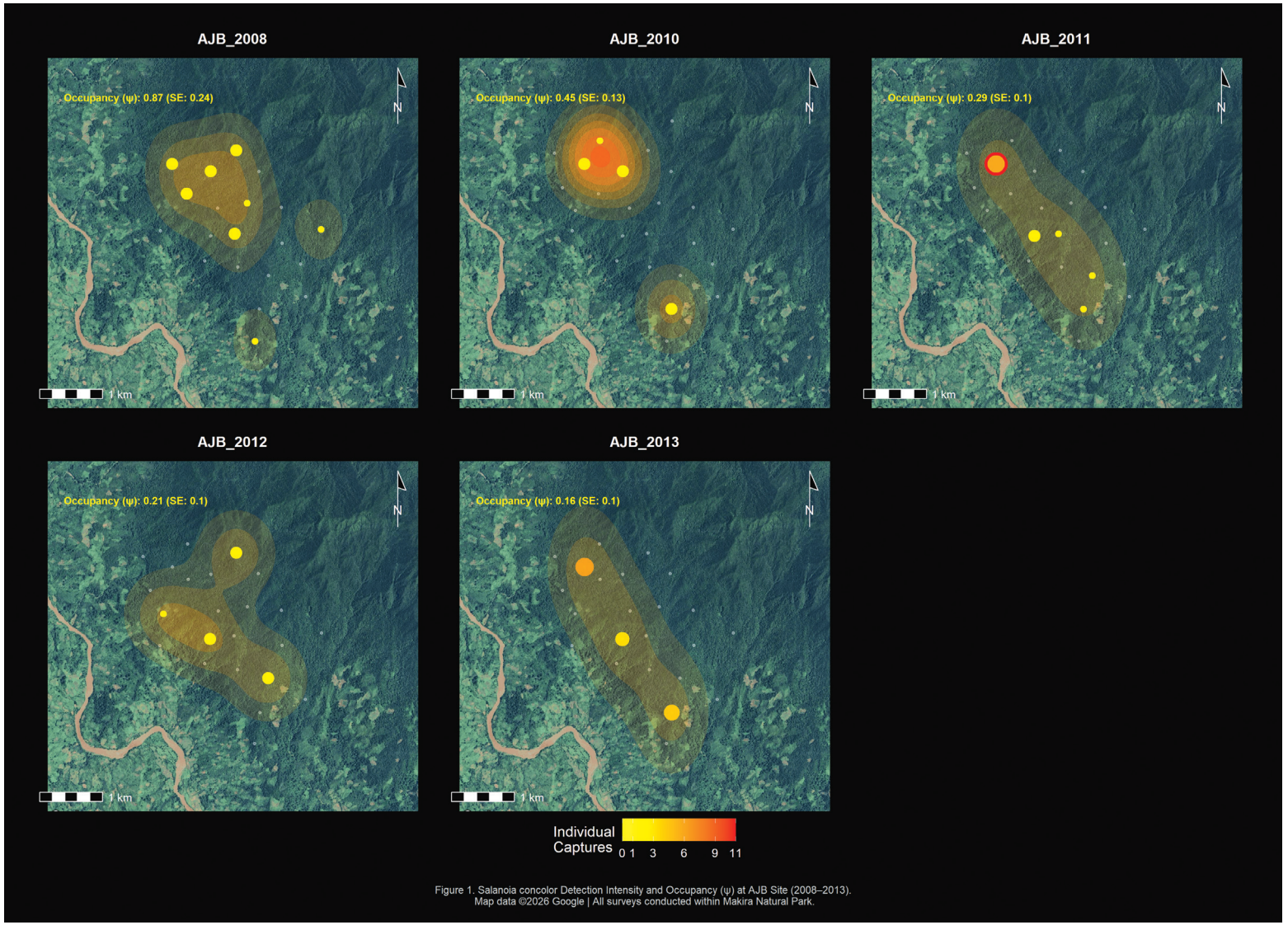

Figure 4. Spatiotemporal distribution and detection intensity of *Salanoia concolor* at the Anjanaharibe (AJB) study site, Parc Naturel Makira (2008-2013). Panels illustrate annual survey results overlaid on high-resolution satellite imagery. White points indicate the full camera trap array (sampling effort). Individual detection events are scaled by frequency (point size) and intensity (yellow-to-red color gradient). The yellow to orange Kernel Density Estimation (KDE) cloud visualizes the spatial concentration of activity, weighted by the number of captures at each station. Annual occupancy estimates (ψ) and standard errors (SE) are provided in the upper left corner of each panel. Created using R (version 4.3.1; R Core Team, 2023).

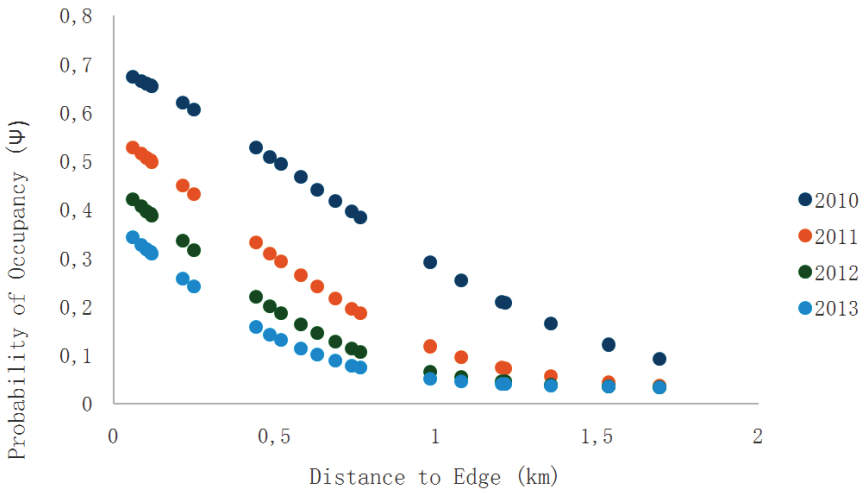

Figure 5. *Salanoia concolor* probability of occupancy by year (2010-2013) as a function of distance to forest edge. Each year shows a similar positive relationship between *Salanoia* occurrence and forest edge, while at the same time continuing to decrease in spatial occurrence each year. These data were collected from 24 sites across the Anjanaharibe site within the Parc Naturel Makira from 2008 to 2013.

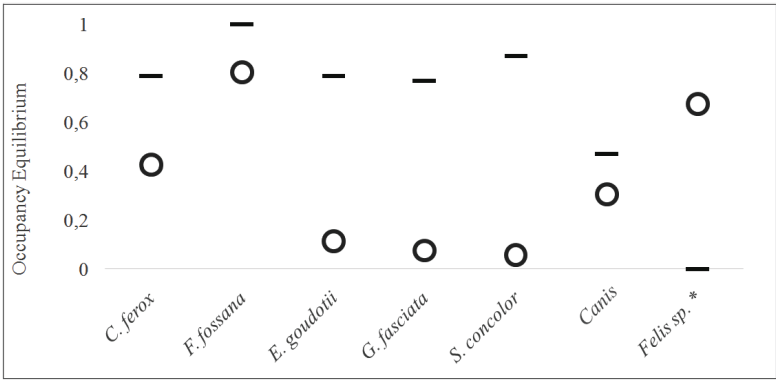

Figure 6. Occupancy equilibrium resulting from multi-season occupancy modeling for native (*Cryptoprocta ferox, Fossa fossana, Eupleres goudotii, Galidictis fasciata,* and *Salanoia concolor*), as well as non-native (*Canis familiaris** and *Felis catus**) carnivorans across the Anjanaharibe site in the Parc Naturel Makira from 2008-2013. Results compare initial occupancy in 2008 (line) to final occupancy in 2013 (circle) for each species.

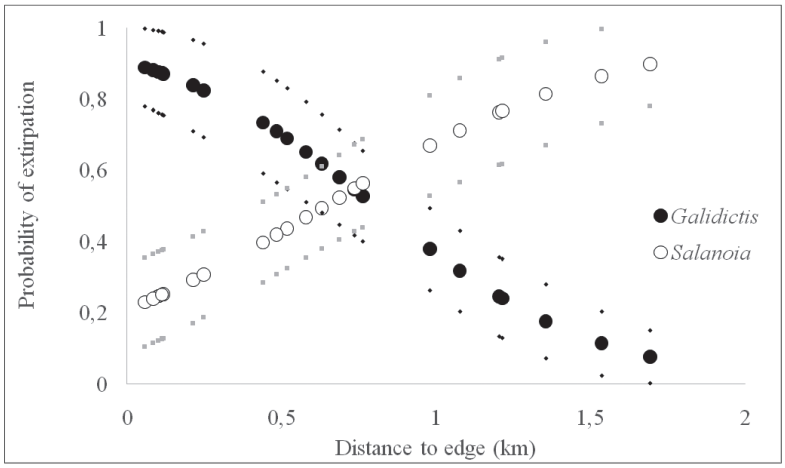

Figure 7. Divergent probabilities of local extirpation for *Galidictis fasciata* and *Salanoia concolor* relative to forest edge distance at the Anjanaharibe site in the Parc Naturel Makira. *Galidictis fasciata* exhibits a higher probability of extirpation near the edge which decreases toward the forest interior, whereas *S. concolor* shows the inverse trend. Smaller points represent 95% confidence intervals. These opposing responses underscore niche separation between the species and suggest that habitat fragmentation impacts these small carnivores in fundamentally different ways.

indica, across all of Madagascar (Wampole *et al.*, 2021) these analyses and subsequent results are important for understanding how *Salanoia* space use is impacted by these exotic species.

The limited number of camera trap captures of *Salanoia* during our surveys make comparisons more difficult compared to other native carnivorans (Farris *et al.*, 2016). When comparing to free-roaming dogs we found that *Salanoia* demonstrates slight spatial avoidance (SIF = 0.91 ± 0.01). However, their probability of occurrence was the same in sites where dogs were present (psi BA = 0.31) compared to sites where dogs were absent (psi Ba = 0.31). The top-ranking model shows the patchiness or total number of forest patches is best at explaining this slight avoidance between *Salanoia* and dogs. We found no clear relationship between *Salanoia* and *Felis catus* across the study zones with *Salanoia* having the same estimate of occupancy at sites where cats were present (psi BA = 0.13) compared to where they were absent (psi Ba = 0.13). This relationship is likely a result of the low capture rate of both species across all our survey sites. Finally, for *V. indica* we lacked sufficient data to model this relationship.

Temporal analyses and results

Using all data from sites across Makira, we investigated temporal (diel) activity for *Salanoia*. We used Kernal Density Estimation to quantify time spent within each time period (day, night, dawn, dusk) based on total availability (10 hours, 10 hours, two hours, and two hours, respectively) (Farris *et al.*, 2015a). We found *Salanoia* demonstrated strong diurnal activity with 54 total observations coming from day time hours and four observations from the dawn period. No observations were made for this species during night or dusk periods for the entire six-year study. This resulted in a strong estimate of diurnal behavior with only very slight probabilities of activity during dawn and dusk (Figure 8).

Further, we investigated temporal overlap with all co-occurring carnivorans (native and non-native) by predicting percent overlap (d-hat) in the Kernal Density Estimation framework (Farris *et al.*, 2015a). We compared *Salanoia* activity overlap with the two native carnivorans of similar body size (*Galidia elegans* and *Galidictis fasciata*) and found strong probability of overlap (d-hat = 0.87) with the diurnal *Galidia elegans*, but very little to no overlap (d-hat = 0.11) with the nocturnal *Galidictis fasciata* (Figure 9A-B). For non-native carnivorans, *Salanoia* had strong overlap with *Canis familiaris* (d-hat = 0.88) across sites where they were both active (Figure 9C).

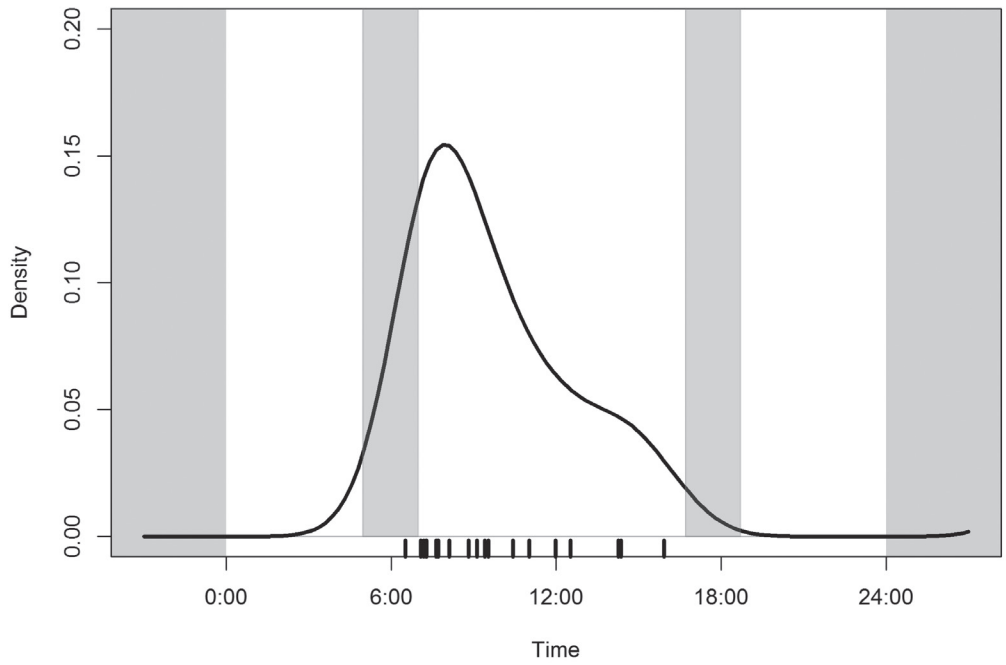

Figure 8. Probability of *Salanoia concolor* activity across the diel (24 hour period) in the Parc Naturel Makira revealing strong diurnal activity. Black bars along x-axis reveal individual captures of *Salanoia* at each time period they occurred. Gray, vertical bars indicate dawn (6:00) and dusk (18:00) time periods. Data for these models were collected from 2008 to 2013 across seven sites in and bordering the protected area.

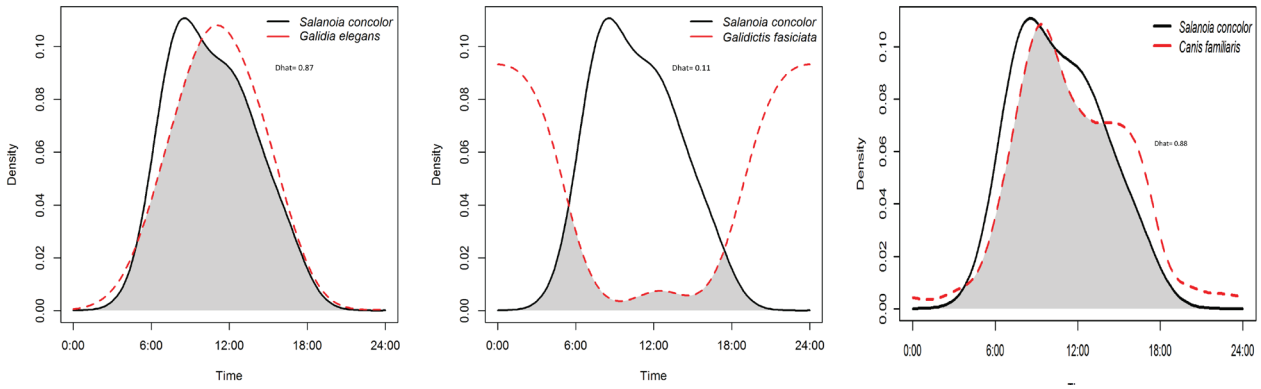

Figure 9. A) Probability of temporal overlap for *Salanoia concolor* and the native, diurnal *Galidia elegans*; **B**) Probability of temporal overlap for *Salanoia concolor* and the native, nocturnal *Galidictis fasciata*; and **C**), Probability of temporal overlap for *Salanoia concolor* and non-native, diurnal *Canis familiaris* across the Parc Naturel Makira. Each species diel activity is plotted with overlap occurring in gray, shaded area. Estimates of overlap (d-hat) are provided for each species comparison.

Conservation and management recommendations

The camera trap surveys we conducted in the Parc Naturel Makira represent the first comprehensive investigation into the habitat selection, ecology, and behavior of *Salanoia concolor*. Despite Makira forming an important portion of its known distributional range, *S. concolor* remains exceptionally rare across Makira. It relies on specific habitat and resource features that remain unclear and understudied. This information gap prevents the identification of essential habitat features, stalling the development of targeted, long-term management strategies.

Our data demonstrates *Salanoia*'s need for intact, non-degraded forest with little to no human activity and disturbance. We also show that *Salanoia* may prefer or strongly require access to low-lying, wet areas and/or water sources, though this requires further exploration. Most concerning are the long-term declines of *Salanoia* across the Anjanaharibe site in the Makira over the course of the period from 2008 to 2013, which reveals a high probability of local extirpation from at least this portion of the protected area, particularly along forest edge. These multi-season trends are alarming. Additional follow-up surveys and population estimates are needed at Anjanaharibe and other sites like it, to learn whether the species is now missing from the site or if recovery and/or restoration is possible.

The presence of free roaming dogs and cats presents a separate and also severe threat in regards to harassment, hunting, spread of zoonotic diseases, and resource competition (Farris *et al.*, 2015a, 2015b, 2016, 2017; Rasambainarivo *et al.*, 2017; Rasambainarivo & Goodman, 2018). Our results show that strong spatial and temporal overlap with free-roaming dogs and humans are a threat to *Salanoia*. Our research shows that this species spatially avoids dogs, and that *Salanoia* populations respond negatively to their presence. Given *Salanoia*'s extremely limited geographic distribution, it is uniquely vulnerable to pressures from these invasive carnivorans. The expanding overlap between native carnivorans and domestic animals constitutes a novel threat that must be mitigated. We believe that effective management, specifically strategies that reduce or eliminate interactions between *Salanoia*, non-native carnivores, and people is essential for the species' long-term survival.

Salanoia concolor is arguably one of the most understudied and threatened endemic carnivorans to Madagascar and the world. These findings underscore a critical conservation crisis within the Eupleridae, a family already recognized as the most threatened carnivore group globally (Brooke *et al.*, 2014). An in-depth, long-term investigation of *S. concolor* is needed to further investigate the species' range, behavior, ecology, and population dynamics. Without these data and a transition to targeted data driven actions, we are likely to see continued declines in this rare, threatened species, leading to further local extirpations and an eventual extinction of the species in the wild.

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