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Regulation of the small Indian mongoose in Martinique: Assessing the effectiveness of two types of traps to optimise population management

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Introduction

Invasive alien species (IAS) have contributed to 40% of recorded species extinctions over the last 400 years (IUCN, 2018). They are one of the significant drivers of biodiversity loss and species extinctions (Bellard et al., 2016). An exotic or alien species is a species which is present outside its natural range due to anthropogenic activities (introduced by humans voluntarily or incidentally), thus extending its distribution area (Soubeyran et al., 2011). When these exotic species manage to establish themselves in a new environment and increase their populations to the detriment of native species, they are considered as invasive. Their introduction and spread threaten biological diversity and can drastically reduce the populations of native species or even lead them to go extinct (Atkinson, 1996; IUCN, 2022). These species can have significant ecological, economic and health consequences (Reaser et al., 2007; Soubeyran et al., 2011), thus, preventing or mitigating their impact is paramount.

Island ecosystems are particularly threatened by invasive alien species (Reaser et al., 2007; Spatz et al., 2017). The main reasons are their evolutionary isolation, taxonomic and functional imbalance (absence of certain biological groups) and the high rate of endemic native species, i.e. species whose geographical distribution is limited to a territory and are not found elsewhere in their natural state. On islands, geographical isolation has often led to the development of unique ecosystems in which flora and fauna have evolved without predators or competition, making these species more vulnerable to competition or predation should an invasive alien species be introduced (Courchamp et al., 2003; Reaser et al., 2007). According to the IUCN world list, IAS jeopardised 46% of terrestrial species considered threatened (classified CR, EN, VU) in the French overseas collectivities. They are to blame for 55% of terrestrial species extinctions recorded in these territories.

Martinique is a 4,000 km long French island in the Caribbean archipelago between the Gulf of Mexico and the western Atlantic Ocean. Martinique is home to a high level of biodiversity, with a high rate of endemism, where the conservation of marine and terrestrial biodiversity is essential and is classified as one of the world's 34 biodiversity hotspots (Myers et al., 2000; Mittermeier et al., 2011). However, 40 invasive alien animal species are registered in Martinique (DEAL Martinique, 2021c), including mammalian predators, such as cats (*Felis catus*), rats (*Rattus* *sp.*), and the small Indian mongoose (*Urva auropunctata*), known to be the most damaging group of IAS for global biodiversity (Lowe et al., 2007; Global Invasive Database, 2023).

The small Indian mongoose (referred to as mongoose in the rest of the report) is among the 100 species (animal and plant) considered the most invasive in the world by the IUCN (Lowe et al., 2007), reputed to be one of the most dangerous introduced predators for native biodiversity (Roy, 2002; Hays & Conant, 2007; Lewis et al., 2011). Originating from the eastern Middle East to southwest Asia, the small Indian mongoose has been voluntarily introduced on more than 64 islands, including Caribbean islands such as Martinique (Barun, 2011; Louppe et al., 2021). The main reasons for its introduction are (1) to combat the proliferation of rats (*Rattus sps.*) that were ravaging sugar cane crops (Barun, 2011; Lorvelec et al., 2021). The stakes were high: Martinique's sugar cane plantations have always played an essential role in the archipelago's economy, along with numerous by-products such as rum. As well as to (2) predate the venomous snake Trigonocephalus (*Bothrops lanceolatus*), species endemic to the island (Dewynter, 2019).

However, this introduction has failed to control the targeted species while leading to the decline and disappearance of several native species. Indeed, as an opportunistic species that quickly became invasive, the small Indian mongoose predates non-selectively on many preys (Berentsen et al., 2017), causing the decline of several species of birds, reptiles, mammals and amphibians in the Caribbean (Seaman & Randall, 1952; Nellis & Small, 1983; Lorvelec et al., 2004; Lorvelec et al., 2007; Hays & Connant, 2007). In Martinique, the mongoose is considered to be primarily responsible for the extinction of an endemic snake, the couresse (*Erythrolamprus cursor*), and two skinks (*Mabuya mabouya and Mabuya metallica*) (ONF, 2020; DEAL, 2021). The mongoose is also suspected of consuming the eggs of other endangered species, such as the White-throated Thrasher (*Ramphocinclus brachyurus*) and the endemic West Indian iguana (*Iguana delicatissima*), both of which are classified as critically endangered and endemic to the island (Son, 2014; Van den Burg et al., 2018).

The small Indian mongoose is also known to predate sea turtle eggs and attack newborns (Seaman & Randall, 1962; Coblentz et Coblentz, 1985). Three species of sea turtle nest on Martinique's beaches and are threatened with extinction according to the IUCN national red list: the leatherback turtle (*Dermochelys coriacea*), classified as vulnerable, the green turtle (*Chelonia mydas*), classified as endangered, and the hawksbill turtle (*Eretmochelys imbricata*), classified as critically endangered and protected at the national level. Although there is no assessment of mongoose exact predation pressure, predated nests are regularly noted during yearly egg-laying surveys (ONF, 2021). Nest predation by mongooses is a significant threat to the populations breeding in Martinique on the rare egg-laying sites that are not heavily anthropised and not very affected by other threats (Nellis & Small, 1983). Several studies suggest that predation rates of 80 to 100% of sea turtle nests by mongooses can be observed in the absence of regulation (Lorvelec et al., 2004).

In addition to the threat to the local fauna, the mongoose has become a significant reservoir of human pathogens such as the rabies virus (Berentsen et al., 2015; Johnson et al., 2016) and the bacteria *Leptospira interrogans* (Shiokawa, 2019; Cranford, 2021).

Thus, controlling mongoose populations has become a priority on several islands to reduce impacts on local fauna and health risks. Several successful eradication programs have been carried out on islands (Barun et al., 2011), notably on the islet of Fajou in Guadeloupe (Lorvelec et al., 2004). However, as eradication is not always feasible, several islands have implemented local lethal population control (Barun et al., 2011). This is the case for numerous Caribbean islands (Quinn et al., 2004; Barun et al., 2011), including Guadeloupe and Martinique (ONF, 2015; ONF, 2020).

Indeed, since 2018, campaigns to regulate the mongoose population have been conducted every year by the National Forestry Office (ONF) in Guadeloupe and Martinique as part of the National Action Plan (PNA) in favour of marine turtles and its action n°17 "preventing predation by invasive and domestic exotic species" (Crillon et al., 2018). These regulation campaigns do not aim to eradicate mongoose populations from the entire coastline but rather to reduce the threat of predation during the sea turtle's nesting period (ONF, 2020).

Since the start of control campaigns, various traps and bait have been tested at several sea turtles' egg-laying sites where traces of predation on nests were reported. The cage trap is the most widely used, a non-lethal trap that requires regular trap surveys and enables only the targeted individuals to be killed. However, in 2021, a lethal trap (DOC250) was tested in Martinique for the first time. DOC250 are already used for mongoose control on several other islands (Peters et al., 2011; Pollock et al., 2013; Kekiwi et al., 2022; Roerk et al., 2022). The advantage of this type of trap is that it does not require as much handling as cage traps and can be left on site to maintain constant control pressure because the trap kills the animal instantly, and there is no need to make regular checks to verify a catch as with cage traps (for animal welfare reasons). The effectiveness of these DOC250 traps compared with cage traps remains unclear, with one recent study stating that they are more effective on mongooses (Kekiwi et al., 2022), while another does not demonstrate this greater effectiveness but speaks of their advantage in terms of cost of use (Roerk et al., 2022). In the field in Martinique during the 2021 control campaign, these traps appear to be less effective than cage traps on trapping success (Vincent, 2021). However, Vincent's study was mainly focused on the bait preference test and was only performed at one site for a short period. Furthermore, previous control operations in Martinique have not investigated the density or abundance of the mongoose population before and after campaigns (with photographic traps, for example), which could give insight to assess the effectiveness of the regulation (Roy, 2001; Rowcliffe et al., 2008: Palencia et al., 2022).

The main aim of this study is thus to compare the efficiency between the DOC250 and the cage traps in the field and assess the regulation campaign effectiveness. Our second objective is to compare trapping effort and efficiency between our trapping campaign and previous years and highlight potential environmental variables influencing the regulation's success.

To answer these objectives, we will test the efficiency of DOC250 and cage traps in capturing mongooses and not capturing non-targeted species and their ability to be operational. We will also estimate mongoose density before and after control sessions to assess the efficiency of the regulation campaign. The superficies of the trapping area of each regulation campaign since 2020 will be calculated, as well as the effort of trapping per year. Finally, different environmental variables will be tested to see if they impact the efficiency of trapping.

Materials and Methods

This study was carried out in the framework of the French Action Plan for sea turtle conservation (PNA) and was conducted through a partnership between the National Forestry Office (ONF) and the French Biodiversity Office (OFB).

1. Study Species and Sites

The target species of this campaign is the small Indian mongoose (*Urva auropunctata*), but also the two species of rats, the black rat (*Rattus Rattus*) and the brown rat (*Rattus norvegicus*) present on the sites as they are also categorised as invasive alien species. Their capture and killing are authorised by prefectural decree (Arrêté, 2013) for some establishments such as the ONF.

The small Indian mongoose measures 51 to 67 cm from head to tail. Body mass varies from 305 to 662 g, with an average of 434 g (females are, on average smaller and lighter than males) (Nellis, 1989). Life expectancy in the wild is 3-4 years. Females have a gestation period of about 7 weeks, and the young become independent after 22 weeks when they weigh between 150 and 250 g.

Two study sites were chosen for the 2023 trapping campaign (Figure 1).

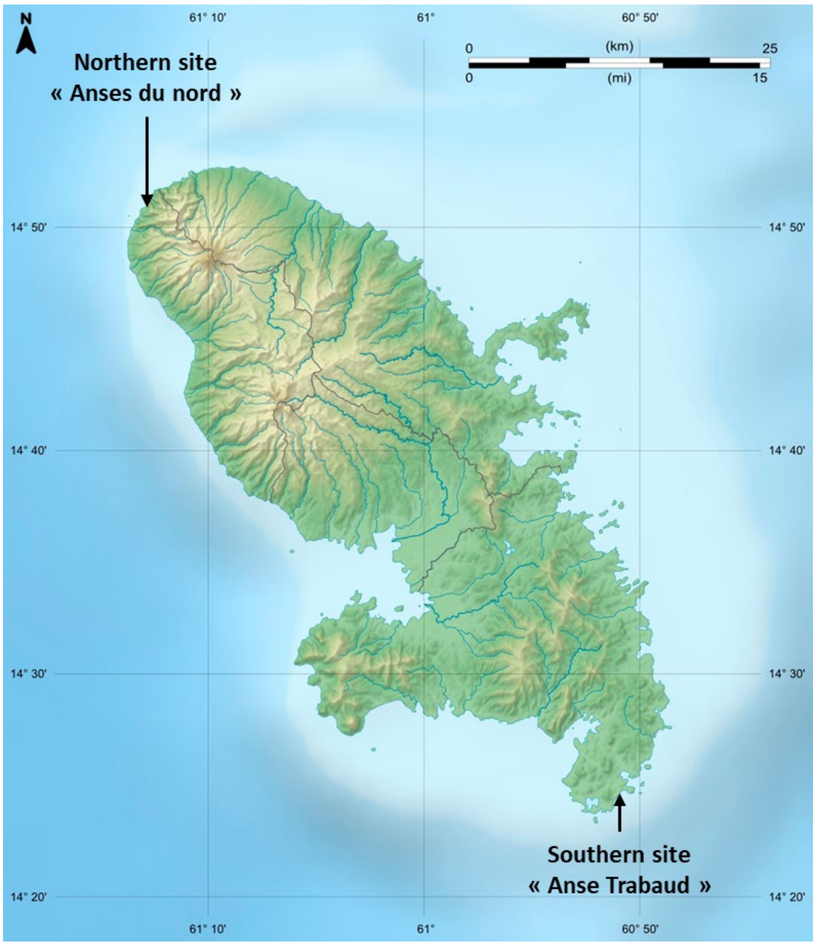

Figure 1. Map of Martinique showing the two sites for the 2023 control campaign

The first site, “Anses du Nord”, is located in the town of Le Prêcheur, northwest of the island, within the Prêcheur-Grand’Rivière integral biological reserve (IBR) (Arrêté, 2014). This northern site is composed of three beaches: Anse Couleuvre (99 m-long), Anse Lévrier (94 m) and Anse à Voile (106 m), linked by hiking trails in a mesophilic forest. Every year, this site hosts many hawksbill turtles (*Eretmochelys imbricata*) and green turtle (*Chelonia mydas*) nestings, as well as a few leatherback turtles (*Dermochelys coriacea*). It is also home to the West Indian Iguana (*Iguana delicatissima*), an endemic species protected and critically endangered (IUCN, 2020; PNA 2018-2022), which also lays its eggs in the backshore (behaviour still poorly documented).

The second site, “Anse Trabaud”, is located in the commune of Sainte-Anne, southeast of the island. This southern site of 1.6 km long is composed of a 953 m-long beach, coastal forest, dry forest, mangrove, and savannah. The beach is an important nesting ground for hawksbill turtles (*Eretmochelys imbricata*) and leatherback turtles (*Dermochelys coriacea*) (ONF, 2020b).

These sites were selected in line with previous control campaigns and the monitoring of sea turtle nesting (Louges, 2018; Gerard, 2019; Caron, 2020; Vincent, 2021; Cafardy, 2022). Indeed, in those sites, mongooses are the main threat to sea turtle nests, where several observations of nest predation are attributed to small Indian mongooses (footprints, excavated eggs). They have been the site of five consecutive regulation campaigns since 2018. These sites also have few or no human constructions, which facilitates the presence of the mongoose known to avoid humans (Quinn et al., 2006; Leighton et al., 2008; Guzmán-Colón et al., 2019). Nevertheless, these sites are becoming increasingly frequented by hikers and passing swimmers.

2. Mongoose Traps

i) Material

For the regulation campaign of 2023, two types of traps were used. On the one hand, 19 non-lethal 36 x 15 x 15 cm traps were custom-built for capturing mongooses by "BTT Mécanique" (see Appendix 1a). The trap is triggered when the animal tries to remove the bait from the hook attached to it at the bottom of the cage. When pulled, the hook activates the mechanism, and the door closes. When a targeted species is captured (i.e. mongoose or rat), it is killed on-site with a 19.9 joules rifle through the cage. When a non-target species, such as the manicou (*Didelphis marsupialis*), the domestic cat (*Felis catus*) or the hermit crab (*Pagurus bernhardus*), was caught, the animal was released directly on-site. Regarding animal welfare, daily monitoring must be carried out to ensure that captured animals remain in the trap for less than 24 hours. These traps have been used successfully since 2018 by the ONF for mongoose regulation.

On the other hand, 19 lethal traps (DOC250) came from the manufacturer “Curtis Metal Product”. These lethal traps are manually reset spring-loaded traps placed in a 40 x 30 x 25 cm wooden trapping tunnel (see Appendix 1b). The trapping tunnel comprises two grids of 2 cm mesh 10 cm apart with 8 x 8 cm openings, a 12 cm screw to hold the bait, and a grid to close the trap. The two grids with staggered holes minimise the risk of non-target species entering the trap and guide the mongoose onto the platform. The animal's weight on the platform will trigger the mechanism, and the trap will close on the animal, thus causing its immediate death by crushing. The DOC250 have been calibrated so that the minimum weight required to trigger it is 100 grams.

The traps were baited with chicken sausage pieces. This choice is in line with previous campaigns where this bait was conclusive after comparing different types of bait (Vincent, 2021). Several other studies have also used this bait (Marshall et al., 2008; Pitt et al., 2015; Owen, 2017), which has the advantage of being easy to transport and use in the field, as it hangs adequately on the hook and does not easily fall off before the cage has been activated, which would render the baiting device inoperative.

ii) Methods

In previous control campaigns, traps were placed exclusively along a linear stretch of beach with a dense mesh; the distances between traps varied from 10 m to 30 m, covering a small area (Caron, 2020; Vincent, 2021; Cafardy, 2022). However, a recent study recommends using two traps per home range (Sauvé et al., 2022).

For the 2023 regulation campaign, the main improvement to the protocol is the extension of the area sampled into the forest to cover a more comprehensive grid (Appendix 2 & 3). Indeed, the inter-trap distance can be determined from the home range size or the length of the maximum mean movements (MMDM) covered by the mongoose. Two traps per home range were installed to optimise trapping, with the inter-trap distance corresponding to half the MMDM (known as the HMMDM). Given that no data are available on the movements or home range of mongooses in Martinique and that these estimates vary greatly depending on the study and the season (Quinn & Whisson, 2005; Sauvé et al., 2022; Berentsen et al., 2020), it was assumed that mongooses travel an average of 160 to 180 metres per day, so an inter-trap distance of 75 to 90m could be used (Benoit Pisanu, comm. pers.).

The traps were to be placed at the intersections of a grid measuring 88 m x 88 m, starting at the edge between the beach and the coastal forest to provide shade for the traps and to take account of the preferred nesting area of green and hawksbill turtles (Leighton et al., 2008).

However, when the theoretical position of the trap was topographically inaccessible, with vegetation density too dense or too far from the trail, the trap's position was adapted. Consequently, the 38 traps are not always located at an equidistance of 88m from each other. The two types of traps were placed as alternately as possible to ensure an even distribution. Their positions were reversed between the two sessions (i.e. DOC250 vs cage traps) to erase the potential impact of trap location on the number of captures for each type of trap. When the traps were set, the characteristics of their location environment (vegetation cover, distance to the trail and the beach) and their GPS coordinates were recorded.

The regulation sessions were organised between March and July 2023, when sea turtle egg-laying activity was at its highest (ONF, 2021). Two regulation sessions spaced 8 and 7 weeks apart were conducted for the northern and southern sites (Figure 2) to ensure sufficient trapping pressure to limit predation on sea turtle nests. A session consisted of one day of trap setting, ten days of trapping and one day of trap removal.

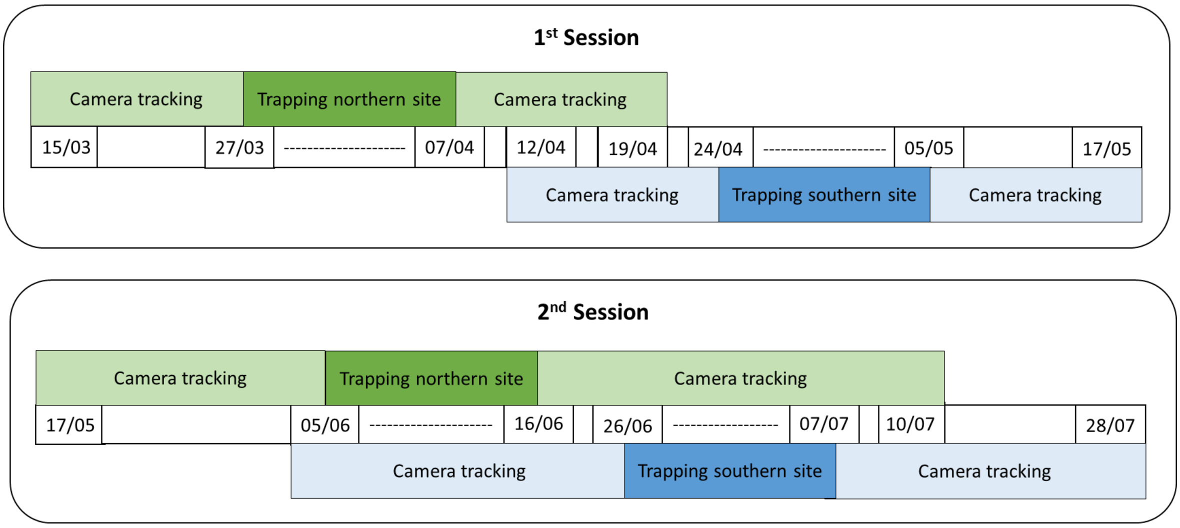

Figure 2. Schedule of the two regulation sessions on the northern site (in green) and the southern site (in blue), with dates for setting and removing trap cameras and mongoose traps

The traps were active 24 hours a day and were checked daily to renew the bait and reactivate the trap, generally between 8:00 am and 2:00 pm, always following the same route to ensure approximately 24 hours between each trap survey. When surveyed, the following information about the trap was recorded in an offline form: date, time, session number, site, trap number, trap status (open with bait, open without bait, closed with bait, closed without bait, animal caught), species if applicable, and the day's weather. These data were then collected in an Excel database.

When a mongoose was trapped and killed, single-use gloves were used to handle the individual, measured using a ruler (head-cloaca and head-tail length), weighed using a scale, and its sex was determined. The corpses were packed in 30 x 40 cm freezer bags, where the location, day of capture, trap number and species were written, then transported in a cooler and stored in a freezer until given to the renderer. Some of the captured animals were kept for dissection and further analysis by the OFB, particularly females, to analyse their reproductive status and potential number of embryos.

3. Camera Traps

To assess the effectiveness of the trapping session, the density of mongooses before and after trapping was estimated using camera traps (see Rendall et al., 2014; Santini et al., 2022; Palencia et al., 2022).

A total of 12 camera traps (Stealth cam GMAX32NG model) were deployed on the northern site, and 14 camera traps on the southern site (Stealth cam GMAX32NG, Bolyguard SG2060-X, Browning n°BTC-8E and Bushnell model 119977C). However, the Stealthcam replaced the Bolyguard models after session one at the southern site due to operational problems.

The camera traps were set on a precise GPS location (see Appendix 2 & 3) 13 days before and 13 days after each trapping session. Following operational problems during session one at the northern site, the deployment of camera traps was extended for a minimum of 22 days for the second session at both sites to obtain more usable data (Figure 2). The photo traps were placed at the intersections of a 150 x 150 m grid starting at the edge of the coastal forest.

Camera traps were installed in a protective metal case, strapped around a tree 30 to 50 cm from the ground, and secured with a lock (python model). The orientation of traps was chosen according to the vegetation to ensure linear visibility for at least 8 meters in front of the camera. Vegetation in front of the cameras was removed to prevent accidental triggering.

Camera traps were active 24 hours a day, with photo timestamping. Detection sensitivity was the highest possible, with low resolution (8mp). Cameras were set to take a burst of 3 consecutive photos at each trigger, with the minimum possible delay between photos (1 second) and the minimum delay between triggers (3 seconds). For the second photo-trapping session, the settings were changed to a maximum of 9 photos per burst to have more data.

When a camera trap was installed, its detection field was calibrated. This staking allows us to obtain photos with visual landmarks at known distances from the camera, which can then be compared with photos where a mongoose is present to measure its distance to the photo trap. The staking method based on that of Palencia et al. (2021) involves taking photos of a 1m stick graduated every 20cm at around ten different positions in the camera's field of detection (between 50cm and 8m away from the camera). The stick must be kept vertical and touching the ground (see Appendix 4). The resulting photos are used to calibrate the deployment. This method was done for each site's deployments before and after session 2.

To obtain the distances automatically by © Agouti software, we need (1) the calibration of the photo trap in the field and (2) the calibration of each model of the photo trap for a given resolution (with the stick like in the field but on flat and clear ground). From these two calibrations, Agouti builds a map and can assign a distance to each pixel, which can then be used to estimate the distance to the individual.

On Agouti, developed to process data from camera traps, photos were sorted by deployment (period of activity of a photo trap at a given station) and then by sequence (all photos taken within a time interval of fewer than 2 minutes). Each sequence can then be annotated when a photo shows an individual whose species can be determined. For each individual observed, its position is noted by a marker on the photo sequence so that its route through the camera field is "traced". Sequences without animals are annotated as "empty". These annotations enable us to automatically obtain the animal's distance, speed, and detection angle from the camera.

4. Statistical Analyses

i) Trapping surface

Without precise knowledge of the amplitudes of mongoose movements in Martinique, the HMMDM width was taken from the literature. The MMDM estimated by Sauvé et al. (2022) in dry forest was used, i.e. 238 m for the MMDM and 119 m for the HMMDM. The effective trapping area was obtained by grouping 119 m circular buffers (a strip corresponding to half the width of the theoretical average maximum distance travelled by individuals) around the traps using QGIS 3.0.2 software. The trapping zones for this year and previous years were thus calculated.

The number of captures per unit effort (CPUE = number of captures/number of days*number of traps deployed) was also calculated for each year to compare the campaigns' efficiency.

ii) Statistical Analyses: GLM and GLMM

We had a set of 3 explanatory variables (trap type, session number, site) and 3 environmental explanatory variables (previous day's rainfall, distance to road, distance to the beach). Rainfall data were acquired from the historical weather website. All other data were obtained in the field. We calculated on QGIS 3.0.2 software (distance in meters (m) from each trap location to the nearest coastal shoreline and to the human trail). The correlations of the environmental variables were tested, but none emerged as correlated with another, so they could all be kept for the analyses.

Firstly, we ran a series of models to test the variables influencing the number of mongooses caught. We performed Generalised Linear Models (GLM) with a Poisson family and a logarithmic link function with the type of trap, site, session number and rainfall as fixed variables. The initial models included all the variables considered. More precisely, we tested all the variables and the interactions between the type of trap and the other variables, assuming that the success of the type of trap on the number of captures may be linked to other variables.

We then used the initial model to select models using the dredge function in the "MuMIn" package (Barton, 2020), using Akaike's Information Criterion. A model was considered the most explanatory when ΔAIC differed by more than two units from all the other models. We checked the dispersion of the residuals and the percentage of variance explained by the model using the "rsq" package.

Similar GLM (Poisson family, logarithmic link function) models were run on the number of rats trapped during the regulation campaign, as well as on the number of non-targeted species and the number of times the traps were inactive (i.e. open without bait, closed with or without bait).

Then, we performed generalised linear mixed models (GLMMs) with a binomial family and a logit link function, using the glmer function from the "lme4" package to determine whether the type of trap, the session, the site, and other environmental variables (distance to the beach, distance to the trail, previous day's rainfall) had a significant effect on the probability to trap a mongoose. The data were reformatted for these analyses so that a mongoose capture (success) was 1 and all other trap states (operational, inactive or other species captured) equalled 0. For these GLMMs, we defined the trap number as a random effect to take account of the possible variation in sensitivity between traps due to their calibration, independently of the type of trap. Then, two other series of GLMMs were carried out for each site (northern and southern) to observe the differences specific to each location.

In the same way, as for the GLMs, a series of models was run to test the variables influencing the probability of capturing a mongoose, with all the variables initially considered. Then, the different models were compared to select the most competitive one, which best explained the effect of the other variables on the response variable.

All analyses were conducted using the free statistical software R 4.1.2 (R Development Core Team). In all models tested, residual dispersion and explained deviance were checked using the "DHARMa" and "MuMIn" packages. Models were visualised using the packages "gtsummary", "effects", and "GGally". Two-way comparisons, when necessary, were performed using the "emmeans" package. All the graphs presented were produced using the "ggplot2" package.

iii) Relative abundance index (RAI)

We also calculated the relative abundance index (RAI) estimated from observations of mongooses in camera traps. The RAI is calculated according to the following equation: 100 *(n/effort), where n corresponds to the number of observations and effort to the number of days (i.e. the number of days the cameras were operating), using the "camptraptor" package. To obtain the overall RAI per session, the number of observations for each camera is added to the effort for each camera, and then the RAI before and after the session is estimated.

iv) Random Encounter Model (REM)

Density by Random Encounter Model (REM) (Rowcliff, 2008) was estimated only for the before and after session 2.

Sub-datasets for deployments were created before and after session 2 of the two sites, including only mongoose observations. The accuracy of each deployment was then checked visually using graphs representing the position of the calibration points on the photo to choose which deployments to exclude from the analysis if the number of calibrations was too low or to correct the annotation of the heights of the calibration stick on Agouti if any points were outliers. Several deployments were corrected for both sites. Detection functions were then adjusted for the data on detection distances, angles and activity. They are then included in the REM model along with the average speed for the specie and the capture rate (i.e. number of animals detected per sampling unit). Finally, the density is estimated for the collective field of view of the cameras (Gilbert et al., 2020) by using the "camtraptor" package and the REM equation (Appendix 5). The variance associated with the encounter rate was estimated by resampling camera locations with replacement by non-parametric bootstrapping (999 iterations).

Results

1. Comparison with previous years

i) Trapping superficies

In 2023, the trapping area was 39 ha at the northern site and 64 ha at the southern site, which is larger than in previous years (Figure 3). There was no data available for the southern site's trapping area for 2022.

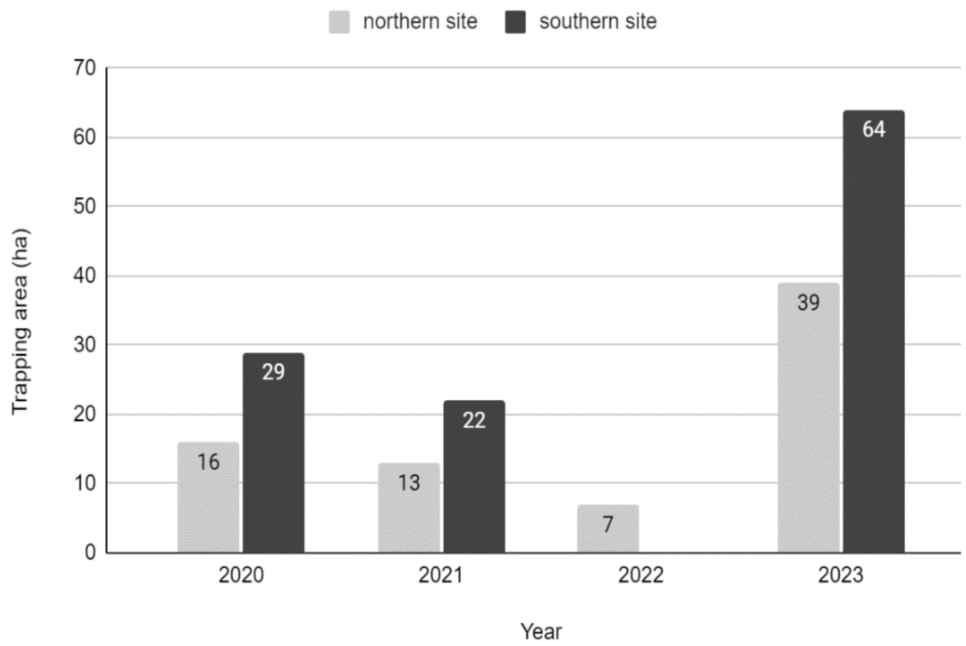

Figure 3. Trapping area in hectares for each site per year

ii) Effort of trapping and CPUE

During the 2023 control campaign, 141 mongooses were trapped during 44 trapping days in the 38 traps deployed. The number of captures per unit effort in 2023 is 0.08 (both types of traps considered). The number of mongooses trapped and the CPUE are higher than the regulation campaign of previous years (Table 1).

Table 1. CPUE from 2020 to 2023 (detailed by type of traps)

Year	Nb of trapping days	Nb of mongoose caught	Type of traps	Nb of traps	CPUE
2023	44	78	DOC250	19	0,09
	44	63	Cage traps	19	0,08
2022	24	36	Cage traps	38	0,04
2021	46	38	Cage traps	38	0,02
	8	1	DOC250	20	0,01
2020	38	83	Cage traps	40	0,05

2. Trapping efficiency between DOC250 and Cage traps

i) Number of mongooses trapped in both sites

During this regulation campaign, 141 mongooses were trapped, and 140 were killed (one escaped from a cage trap).

The best GLM explaining the number of mongooses trapped was the one including the simple variables (site + type of traps + previous day's rainfall + session number) and an interaction (site: type of traps). This model has the lowest Akaike's Information Criterion (AIC=307.95) and 13% of the deviance explicated (R^2).

This model indicates that the session number has a significant effect (E=-0.469±0.173, p=0.007): indeed, the number of captures was significantly higher in session 1 (both sites combined) with 86 mongooses (58% of the total of mongooses caught).

The model indicates no significative difference in the number of mongooses caught between the sites (p=0.188) and between the types of traps (p=0.347). However, the interaction of these two variables significantly affects the number of mongooses trapped (E=-0.916±0.349, p=0.034). The paired comparison shows that the cage traps caught significantly fewer mongooses than the DOC250 at the northern site (Figure 4).

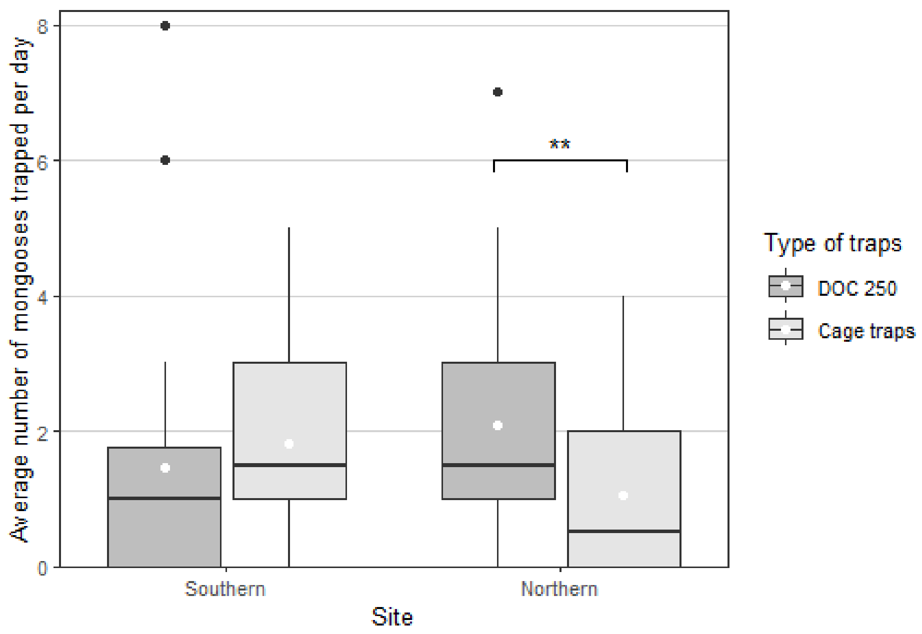

Figure 4. The average number of mongooses captured per day by site and type of traps. Stars show a significant effect ** ($p<0.01$).

The GLM also showed that the amount of rain that fell the day before each survey had a negative influence on the number of captures, i.e. the more it rained the day before the survey, the lower the number of mongooses trapped (E=-0.686±0.235, p=0.003, Figure 5).

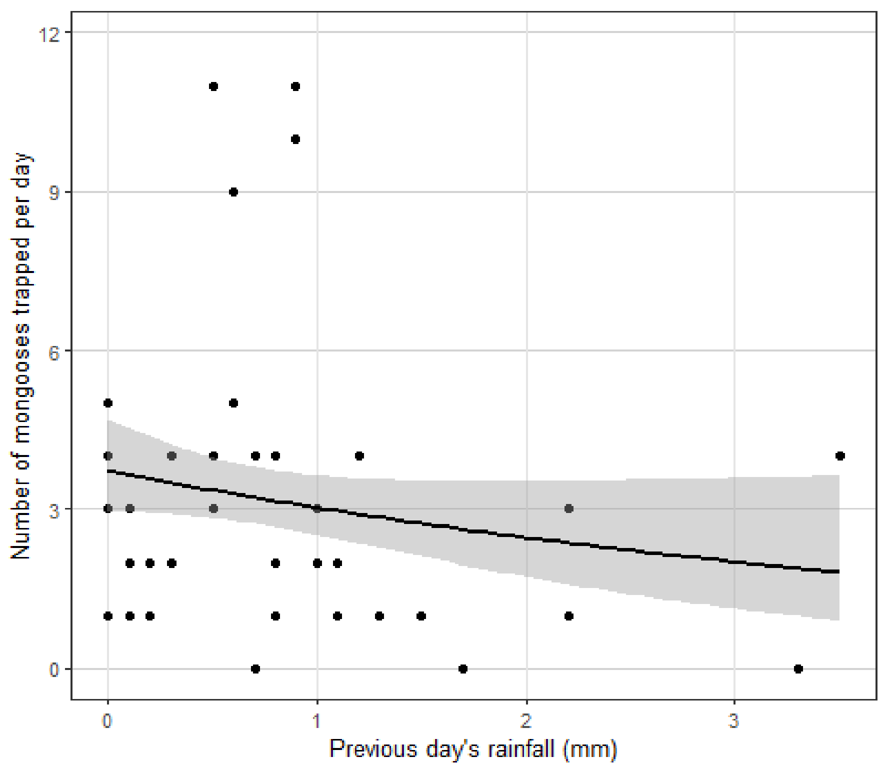

Figure 5. Number of mongooses trapped according to rainfall on the previous day

ii) Number of mongooses trapped at each site

At the northern site, 69 mongooses were caught, i.e. an average of 3.1±2.7 mongooses per day, with 46 of them trapped in DOC250 (for a geographical representation of the trapping distribution see Appendix 6). At the southern site, 72 mongooses were caught, an average of 3.4±2.8 mongooses per day, with 32 of them trapped in DOC250 (see Appendix 7).

The GLM chosen for the northern site had an AIC of 152 and explained 15% of the deviance. The GLM selected for the southern site had an AIC of 155 and explained 11% of the deviance.

The DOC250 caught twice as many mongooses at the northern site as the cage traps (46 vs 23). The results of our model for the northern site showed that the number of mongooses captured was significantly lower for the cage traps (E=-0.693±0.255, p=0.007; Figure 4). At the southern site, 32 mongooses were captured by the DOC250 compared with 40 by the cage traps. The results of our model for the southern site clearly show no effect of trap type on the number of mongooses captured (Figure 4).

In both sites, the number of mongooses captured was lower during session 2 than during session 1: in the northern site, we trapped 39 mongooses during session 1 and 30 during session 2 and in the southern site, 47 during session 1 and 25 during session 2. Our models show that session 2 caught fewer mongooses than session 1 in the southern site (E=-0.631± 0.247, p=0.011), but there was no difference in the northern site.

Finally, in the northern site, the previous day's rain had a negative effect on the number of mongooses caught (E=-0.470± 0.246, p=0.030). The model showed no effect from the previous day's rain at the southern site.

iii) Other species trapped

Over the course of the campaign, seven species were caught, including five non-target species: the manicou (*Didelphis marsupialis*), the hermit crab (*Coenobita clypeatus*), the cat (*Felis catus*), the land crab (*Cardisoma guanhumi*) and the blackbird quail (*Quiscalus lugubris*). During this regulation, mongooses accounted for 47% of the catches, rats for 19%, and the rest were non-targeted species, with mainly crustaceans (24%) (Table 2).

Table 2. Number of individuals trapped by species per site

Number of individuals trapped	Rats	Manicou	Hermit crabs	Land crabs	Cats	Birds
Northern site	52	16	4	0	3	0
Southern site	7	8	65	5	2	2

Non-targeted species

The best model to explain the number of individuals of non-targeted species was based on the following variables (site + type of traps + site: type of traps) and an AICc of 215.43. The model explained 55% of the deviance.

The GLM model showed that the type of traps (E=-1.131±0.257, p<0.001), the site (E=-1.729± 0.327, p<0.001), and the interaction between the two variables (E=1.131± 0.498, p=0.023) have a significant effect on the number of non-targeted species trapped. Indeed, the paired comparison and Figure 6 show that the DOC250 trapped more non-targeted species than the cage traps and that more non-targeted species were caught in the southern site, most of them being hermit crabs (Table 2).

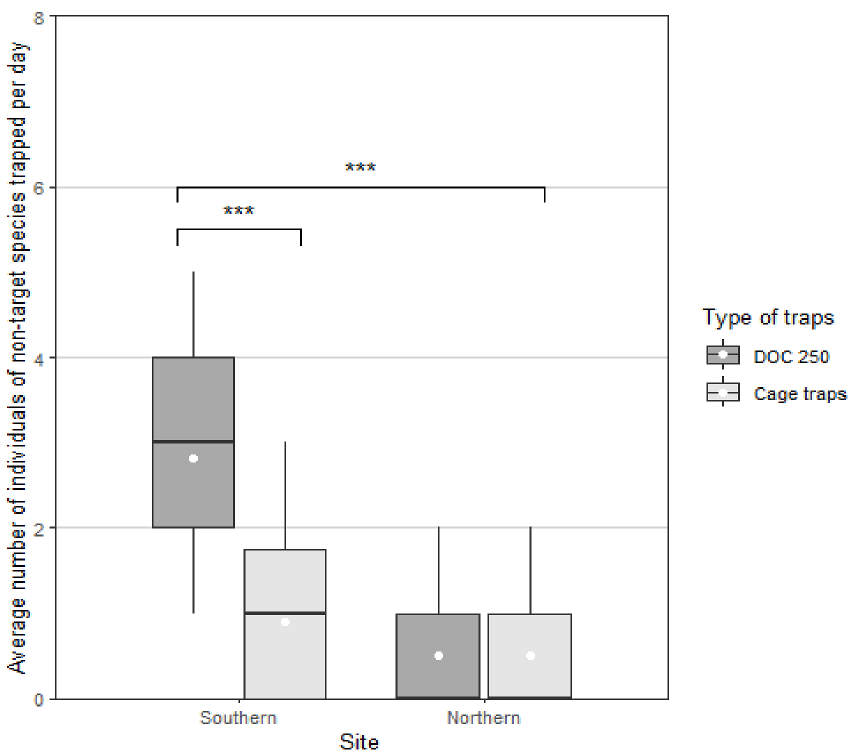

Figure 6. The average number of non-target species individuals caught per day by site and type of traps. Stars show a significant effect *** (p<0.001).

Rats

The 2023 campaign of the mongooses' regulation also enabled the killing of 59 rats (Rattus sps.), an invasive exotic species. This report does not cover the model's results on the number of captured rats because of lack of space.

iv) Traps' inactivity

Concerning trap inactivity, i.e. the states where the trap is not operational and has not captured any animal, the traps were more inactive on the southern than on the northern site (36% vs 19% of the traps were inactive during the two sessions for each location). The GLM model selected to explain the number of inactive traps was based on the following variables (site + type of traps + previous day's rainfall + session number) and an AIC of 384.27. This model explained 57% of the deviance (R^2).

The model showed that the site ($E=-0.668\pm 0.1007$, $p<0.001$), the session number ($E=-0.440\pm 0.096$, $p<0.001$) and the type of traps ($E=0.608\pm0.098$, $p<0.001$) affect the number of inactive traps. Indeed, on average, the number of inactive traps was higher for session 2 (mean±se=12.95±3.14) than for session 1 (mean±se=8.09±5.28). Moreover, the DOC250 were, on average, less inactive (mean±se =3.64±2.40) than the cage traps (mean±se=6.68±3.16) in both sites.

The average number of inactive DOC250 was also lower than the one of inactive cage traps at each site according to our paired comparison, and the traps in the northern site were less inactive than in the southern site (Figure 7).

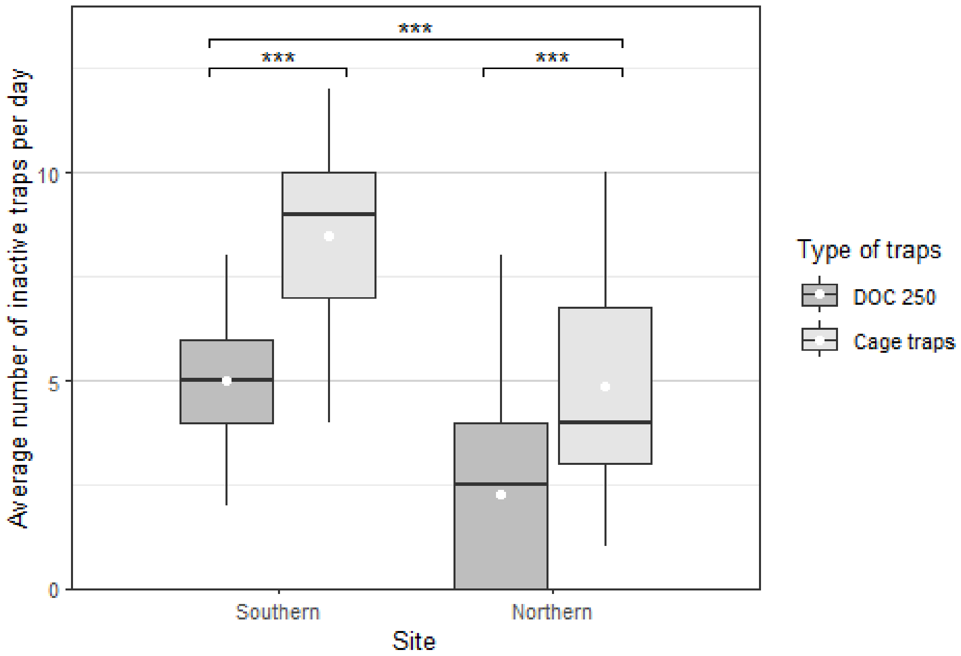

Figure 7. The average number of inactive traps per day by site and type of traps. Stars show a significant effect *** (p<0.001).

3. Other parameters influencing the probability of trapping a mongoose

The analysis of mongoose capture probability for both sites used trap type, session number, site, previous day's rainfall, distance to road and beach, and trap-site interaction as variables. The random effect was the trap number. Model AIC was 925.3, and R2 values were: model=0.09, fixed=0.02, random=0.07. The model indicated that session number (E=-0.540± 0.185, p=0.003), distance to trail (E=-0.009± 0.003, p=0.027) and site-trap interaction (E=-1.133± 0.373, p=0.002) had significant effects on mongoose capture probability. There was also a trend for the previous day's rainfall (E=-0.241± 0.131, p=0.066).

Two GLMMs were conducted per site to determine the probability of trapping a mongoose with greater detail and site specificity.

In the northern site, our model (based on all the simple variables, AIC=458.7, R2 model=0.07, fixed=0.04, random=0.03) showed that the probability of capturing a mongoose was significantly lower for cage traps (E=-0.845±0.314, p=0.007): on average, there is twice the chance of catching a mongoose with DOC250 than with cage traps. We also observed a significant negative effect of the previous day's rainfall on the probability of capturing a mongoose (E=-0.528±0.227, p=0.020). In the northern site, the distance to the beach and the trail significantly affected the likelihood of catching a mongoose (E=0.003±0.001, p=0.034 and E=-0.013 ±0.007, p=0.045, respectively). The further the traps were from the beach, the greater the probability of catching a mongoose (Figure 8). Conversely, the further the traps were from the trail, the lower the capture probability (Figure 8). The session also has a trend effect on the likelihood of capture (E=-0.457±0.267, p=0.086). No interaction had a significant effect on the probability of capture.

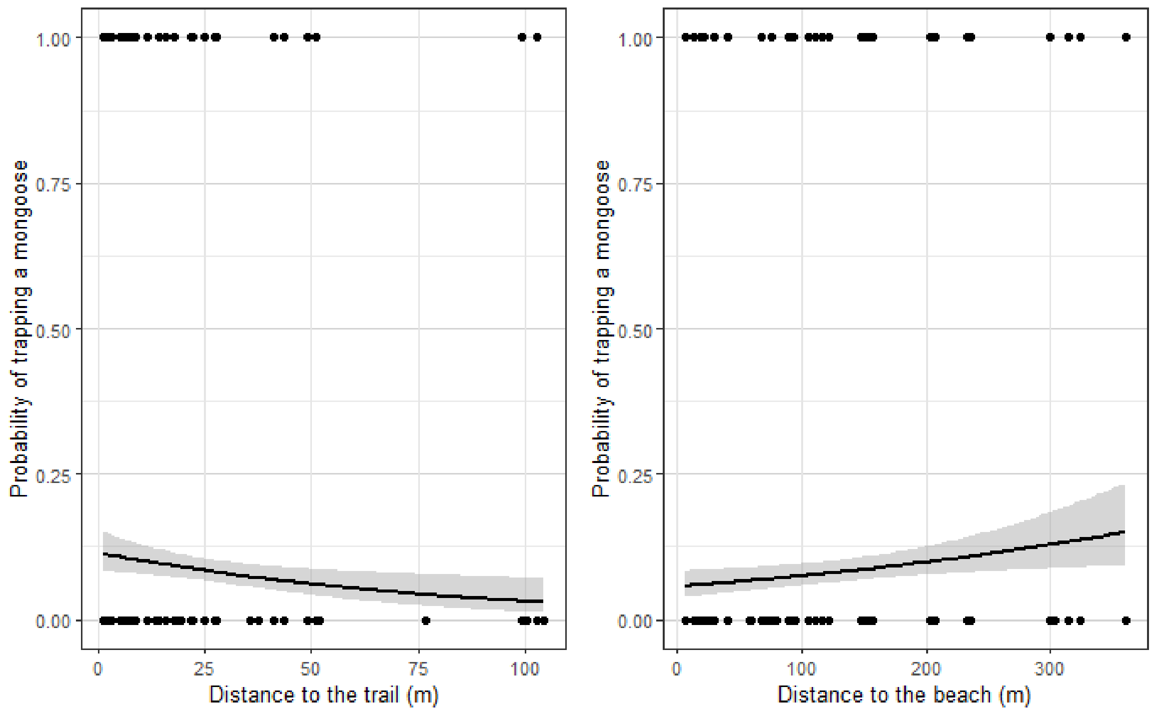

Figure 8. Probability of capturing a mongoose as a function of distance from the beach and distance from the trail in the northern site.

At the southern site, the model (based on session number and distance to the trail, AIC=461, R2 model=0.15, fixed=0.01, random=0.14) revealed that the probability of capturing a mongoose was not affected by the type of trap. However, the capture probability was lower in session 2 than in session 1 (E=-0.715 ± 0.272, p=0.008). The probability of capture was also affected by the distance to the trail (trend: E=-0.007± 0.004, p=0.095): the further the traps were placed from the trail, the lower the probability. The other explanatory variables did not significantly affect the probability of capture in the southern site.

4. Mongoose abundance and density (photo traps)

i) Abundance results (RAI)

The relative abundance indices obtained for both sites decreased after each session. Eight weeks after the first regulation session, the $RAI^{northernsite}$ increased but remained lower than before session 1 (Figure 9). These data should be taken with caution because the number of efforts (in days) is lower for post-session 1 (44.41 compared to 141 for pre-session 1) due to camera malfunctions, with only five cameras out of 12 functioning correctly for these periods (see Appendix 8). The $RAI^{southernsite}$ increased between post-session 1 and pre-session 2, after eight weeks between the two regulation sessions. For both sites, the effort in days is lower before and after session 1 than before and after session 2 because the cameras were installed for a more extended period (see Appendix 9)

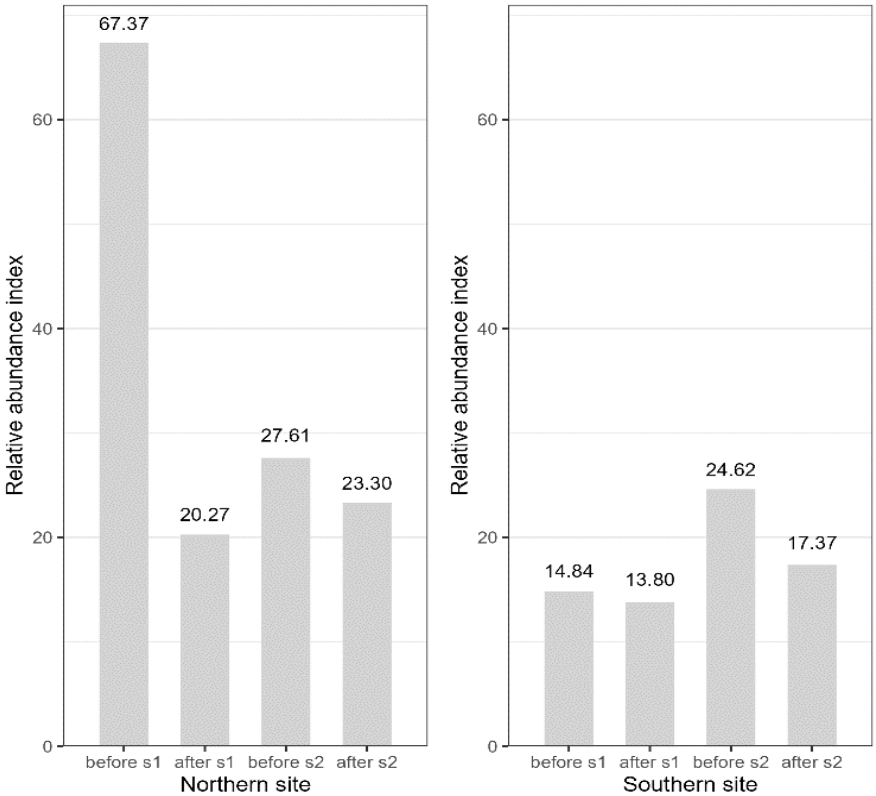

Figure 9. RAI of mongooses in the northern and southern sites before and after each session of regulation

ii) Density results (REM)

The mongoose densities estimated by photographic trapping in the northern site are based on 225 observations with 11 cameras before and 12 after session 2 active. We see a decrease in density after session 2 of the regulation (Figure 10). The mongoose densities estimated by photographic trapping on the southern site are based on 153 observations with 14 cameras before and 13 after session 2 active. We also see a decrease in density after session 2 of the regulation (Figure 10). The density before session 2 is higher on the southern site. The coefficient of variation of the estimated densities varies between 0.46 and 0.64. No deployments have been excluded from the estimate, the difference in the number of deployments between sessions is due to cameras that did not work. Days of setting and removing the camera traps are included.

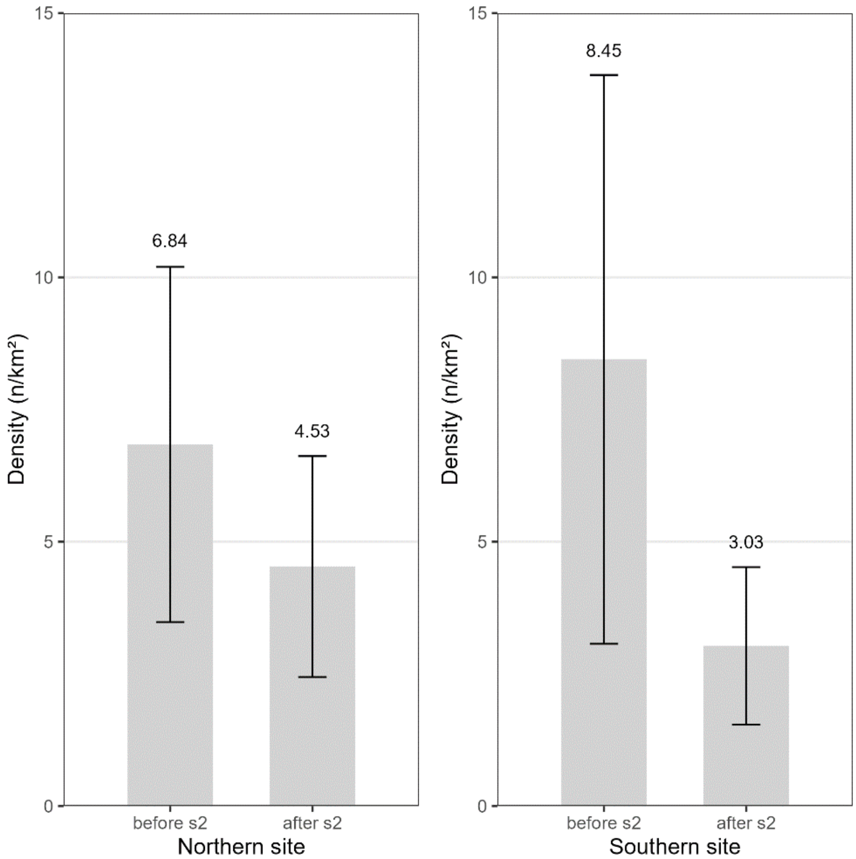

Figure 10. Estimated density (n/km²) before and after session 2 at both sites. The mean and the standard errors are represented.

Discussion

1. Efficiency of the 2023 regulation campaign

Our results showed that the CPUE of the 2023 regulation campaign was higher than in previous years, despite an increase in effort in terms of trapping duration, because there were a higher number of captures. Since CPUE is a standardised value that allows us to compare our trapping effort and efficiency between years (Coblentz & Coblentz, 1985), it can be inferred that the 2023 campaign was more effective than other years in capturing mongooses.

We can also use CPUE data to compare the effectiveness of several types of traps (lethal and non-lethal) (Kekiwi et al., 2022). In our study, there is a slight difference between the CPUE of the two types of traps, with the lethal traps having a slightly higher CPUE than the cage traps for the same effort. Additionally, the CPUE of the DOC250 in 2023 is much higher than the 2021 CPUEs for both DOC250 and cage traps, which shows that the 2021 regulation campaign was not very effective, which may also explain the lack of mongooses captured by DOC250.

One of the reasons for the effectiveness of the 2023 campaign can be explained by the larger trapping area than in previous years, moving from a linear on the beach in years 2020, 2021 and 2022 to a grid from the beach to the forest this year, resulting in a greater distance between traps. Several studies have shown that the effectiveness of trapping depends mainly on the distance between traps and the environment in which they are placed (Pitt et al., 2015). Indeed, in their study in Hawaii, Pitt et al. recommended increasing the inter-trap distance for greater efficiency. However, the inter-trap distance in our regulation campaign could be improved, as it is based on the home range of mongooses at St Kitts (Sauvé et al., 2022; Benoit Pisanu, com. pers.) and not on local data. Indeed, to this date, no studies on home ranges, daily travel distances, and habitat use patterns of mongooses have been conducted in Martinique: measuring this data for the studies sites would greatly benefit the management technique of the small Indian mongoose on the island.

2. Testing DOC250 effectiveness

i) Effectiveness in catching mongooses

During the 2023 regulation campaign, both types of traps used were effective in capturing mongooses. However, our results showed that the effectiveness of our two types of traps was not uniform across the two sites. The greater effectiveness of DOC250 traps compared with cage traps in the northern site is consistent with the results of Peters et al. 2011 in Hawaii. However, our results are contradictory to the results of the 2021 campaign conducted by Vincent (2021), in which DOC250 traps proved ineffective in controlling the small Indian mongoose. Several factors could explain this, particularly the short period over which the traps were tested in 2021 and the fact that they were placed along a linear on the beach with a shorter inter-distance than this year.

However, the fact that mongooses were captured equally by the DOC250 and cage traps on the southern site aligns with recent studies as the one of Roerk et al., 2022 in Hawaii (see also Nishimoto, 2011; Pollock & Hairston, 2013). In the context of our study, the difference in results obtained at the two sites could be explained by the greater abundance of hermit crabs at the southern site, which triggers or deactivate DOC250 more frequently than at the northern site, making them less available to capture mongooses.

ii) Effectiveness in preventing the capture of non-target species

Both types of traps caught more target species (mongooses and rats) than non-target species (manicou, hermit crabs, land crabs, cats and birds) in the 2021 campaign. However, our results show that the DOC250 caught more non-targeted species than the cage traps, especially in the southern site. This can be explained by a large number of crustaceans (especially hermit crabs) which account for the vast majority of accidental catches, particularly at the southern site where the hermit crab population is huge. Hermit crabs enter both types of traps but are only killed (for individuals over 100g) in the DOC250 traps, whereas they rarely even trigger the trap in the cage traps. The problem with hermit crabs is that they tend to stay nearby the spot once they have spotted a bait and systematically trigger the trap once it is re-baited, preventing the potential capture of a target species.

With DOC250, non-target individuals are almost always killed immediately, which can cause problems if native or endangered species enter the trap. However, none of the non-target species captured on the two sites seen during our regulation campaign are threatened or protected. The manicou benefited from strict and specific regulatory protection until 2018 but recent studies have shown that it is an exotic species (non-invasive) not subjected to any control measures (Cattzeflis, 2005). Adapting the entrance to the DOC250 (with a smaller hole in the mesh for instance) could make the trap even more specific to mongooses and prevent manicou (bigger when adults) from entering.

None of the DOC250 caught any birds, although the cage traps did catch two blackbirds that died of sun exposure at the southern site. Therefore, DOC250 do not seem to pose a threat to birds, and could be deployed in areas where protected birds are present. A complementary study will be carried out at the “Pointe à Bibi” site in Martinique where some regulation campaigns take place, to see if the white-throated sparrow, an endemic to the island classed as endangered, tries to get into the traps.

Although cats are considered a non-target species in the campaign, they remain invasive, so their capture is not a problem except for communication and social acceptance by the population.

These accidental catches emphasise the importance of trap adaptation to deter non-targets from entering the trap. Adjusting the trap sensitivity of DOC250 to trigger at a higher threshold would reduce accidental catches of crabs, hermit crabs and potentially birds. Currently, the sensitivity of the traps is set to trigger at an animal weight of 100 g (recommendation of Kekiwi, 2022). However, adjusting the trap sensitivity means there would be less chance of catching rats or juvenile mongooses.

iii) Traps inactivity can impact their availability to capture a mongoose

Regarding inactivity, our results clearly show that the cage traps were most often inactive than DOC250. They were particularly inactive at the southern site because of the presence of hermit crabs which managed to get into the cage and eat the bait without being caught. The theft of bait is much less frequent in DOC250 in general because most of the time the animal is killed as soon as entering the trap. The inactivity in DOC250 may be due to rodents (mice or rats) that are too light to trigger the trap (Kelsey et al., 2019) or small hermit crabs.

Our results imply that cage traps are less available than DOC250 traps for capturing mongooses, which impacts their efficiency in the field.

iv) Use in the field

The precedent results showed the trap's effectiveness without considering the human effort required to set and check these traps. Even if the human effort was not quantified for this report, the two types of traps require different human labour to monitor them. Indeed, the advantage of DOC250 traps is that they do not need to be checked daily (Pollock & Hairston, 2013), which makes them less time-consuming and requires fewer field agents than cage traps. They would be useful where regular trap checks may not be possible due to site remoteness or staff availability. In addition to human resources, the cost of such an operation can be an important parameter in the choice of traps. Although the initial costs of lethal traps are higher, the cost of setting them up in the field and surveying them is more cost-effective than the cage traps when the survey is done once a week (see the study of Roerk et al., 2022).

Furthermore, in the case of cage traps, the animals captured must be killed on the spot using a firearm (rifle), which requires people who are qualified to shoot and comfortable with the idea of killing, whereas DOC250 simply requires the carcass to be removed.

Nevertheless, DOC250 traps are heavy and bulky (around 9.5 kg compared to 500 g for cage traps) and, therefore, difficult to place in steep terrain (Pollock & Hairston, 2013), and require a lot of field agents to set and remove them (in our study, at least six people had to be mobilised to deploy the traps, being able to carry only two DOC250 at a time). In this light, cage traps are easier to deploy and remove, which is useful for short campaigns.

3. Assessing the efficiency of the regulation campaign thanks to camera traps

An index of relative abundance is a count of animal observations that are assumed to correlate with the species' population size. Hence, a change in the index values reflects changes in population size (Jachmann, 2001; O'Brien, 2011; Martin-Garcia, 2022). Our results showed a decrease in mongoose abundance after each trapping session, which indicates a change in population size and therefore informs on the effectiveness of regulation.

In addition, the decrease between before session 1 and before session 2 indicates that the population does not have time to fully recover (through births or immigration) between the two sessions.

The "initial" densities of 0.068 mongooses/ha for the northern site and 0.085 mongooses/ha for the southern site, based on observations made before trapping session 2 (therefore after a first regulation session) constitute the first data on mongoose density established in Martinique. Mongoose density is known to vary between habitats, which are different between the two study sites, and between islands. According to Sauvé et al., 2022, mongoose densities range from 0.19 to 9.0 mongooses/ha in the islands where the species was introduced. Our estimated densities are therefore below what we can find in the literature: in comparison the mongoose average densities range from 0.13 to 0.74 mongooses/ha in Puerto Rico and 2.6-6.4 mongooses/ha in Jamaica (Pitt et al., 2015). We assume that the density of mongooses in Martinique, and in particular on the study site, is not much lower than on these other islands, but rather that our estimates lack precision. An increase in the recording period by the photographic trapping device should make it possible to improve the precision and reliability of the density estimates.

To find out the optimum number of cameras and deployment time for obtaining an accurate density estimate, power tests in the form of a graph of the coefficient of variation as a function of the number of cameras used and the deployment time would make it possible to improve the monitoring strategy. In addition, particular attention needs to be paid to the quality of the camera models, as several models have had technical problems regarding operation, detectability or trigger responsiveness.

Although the density estimate per REM cannot be extrapolated to the scale of the trapping grid because it is estimated on the scale of the cameras' collective detection field, its estimate remains relatively accurate and makes it possible to observe the evolution of the population between before and after regulation.

We argue the necessity of capture-marking-recapture studies, using GPS collars, to acquire data on the density, movements behaviour and home range of mongooses in Martinique and on our study sites (see Conr & Conrnroy, 1998). This knowledge could significantly improve trapping methods and provide a better assessment of the effectiveness of control campaigns for this species. Although it is important to point out that in the context of invasive alien species on French territories, it is illegal to release an individual once it has been caught, hence this type of project would require an exemption.

4. Environmental variables influencing the probability of mongoose capture

While the type of trap explains the probability of mongoose capture for the northern site, other factors seem to have an influence. Indeed, the weather of the day before trapping, particularly rainfall, is a factor that negatively impacts the probability of capture. These results are in line with the results of Vincent (2021) that high rainfall reduced the abundance of mongoose detected on the photo traps in those sites. Several other studies have highlighted that mongooses have a strong aversion to rain and water (Hays & Conant, 2007; Barun et al., 2011; Owen, 2017) and are, therefore, less likely to be caught when it rains (Nellis & Everard, 1983).

Our results also showed that the capture probability was higher away from the beaches at the northern site. These results are interesting because tourists increasingly frequent the beaches of this site and this is consistent with the fact that mongooses tend to avoid humans (Quinn et al., 2006; Leighton et al., 2008, 2010; Guzmán-Colón et al., 2019). Some studies have shown that mongoose behaviour changes when human activity is high, with reduced movements and less frequent feeding behaviour (Quinn et al., 2006). Thus, the increasing number of tourists visiting the sites could therefore help to protect marine turtle nesting beaches from mongooses' predation.

Our results also revealed the greater probability of capture close to the trail at both sites. These results should be seen in the context of the study, where the ease with which most of the traps were set was along paths and over a relatively short period. Other studies, such as Guzman-Colon (2019), show no significant effect of distance from the path on the probability of catching a mongoose. Thus, our first results are interesting but a long-term study with traps even further from trails could be relevant to confirm this effect.

Factors influencing the probability of mongoose captures are not often considered in regulation, yet, these parameters can give insights to adapt the trapping strategy and increase its efficiency, thus it is essential to assess them (Guzmán-Colón et al., 2019; Sauvé et al., 2022).

5. Management recommendation

The only way to put a definitive end to predation by the small Indian mongoose would be the total eradication of the species as it was done successfully on Fajou island (Lorevelec et al, 2004; Barun et al., 2011). However, as Coblentz & Coblentz (1985) point out, that would be difficult to implement in Martinique, which has a much larger surface area than the few islands where eradication has been successful, and it would require enormous financial and human resources.

Hence, the only option remains to reduce populations as much as possible on sensitive sites, as it has been done to date. However, it is necessary to develop an effective protocol adapted to the trapping sites while being aware of limited time and human resources.

We, therefore, recommend combining an intensive trapping operation with cage traps (1 or 2 weeks on the targeted sites) at the start of the sea turtles' nesting season and a more extensive operation using DOC250 to maintain control pressure high during the whole season, with less frequent trap changes (once a week then once a month - depending on their capture rate). The intensive regulation could be renewed once or twice a season, depending on the length of the session chosen. Particular attention should be paid to the distance between the traps and the trapping area. Based on this year's data, the trapping area was appropriate for an intensive campaign. The 2023 trapping area and inter-trap distance seem to be appropriate to have an efficient regulation campaign but further investigation of the home range of the mongoose in Martinique will allow to adapt these parameters.

Concerning the extensive trapping operation, DOC250s could initially be used at the same time as cage traps during the intensive campaign, then left on the field and either checked once a month or during other missions on the sites by ONF field agents. However, as bait attractiveness decreases over time as it degrades, like chicken sausages that dry out quickly under field conditions, another type of bait more suitable in the long term should be considered for the DOC250, such as dried fish for example (Coolman, 2016).

Moreover, solutions need to be explored to prevent the accidental capture of non-target species, in particular, hermit crabs at the southern site. Ideas to be tested include changing the threshold for triggering the DOC250, raising the traps to prevent hermit crabs from climbing into them, or finding a bait that attracts them less than those currently used.

In addition, in order to increase the probability of capture, our study recommends that traps should not be placed too close to beaches or too far from trails. It is also advisable to trap more during dry periods or on sunny days for the intensive operations.

Finally, we argue that it is essential to achieve adaptive management when regulating the small Indian mongoose. Indeed, the managers responsible for controlling this invasive alien species have to maximise this control with limited resources, so obtaining information on how to improve the effectiveness of control techniques while conducting operations is the most appropriate approach.

Conclusion

This study showed the higher effectiveness of DOC250 in capturing mongooses compared with cage traps in the north of Martinique. However, since there was no difference in effectiveness in capturing mongooses at the southern site, resource managers can use other parameters, such as cost or human labour, to choose the mongoose regulation method. We advise that DOC250 should be used long-term as part of a permanent trapping regime to reduce the seasonal predation of mongooses on sea turtle nests.

In addition, other parameters are essential to take into account to optimise control operations, such as the distance between traps and the trapping area, which must be adapted and based, if possible, in the future on density and home range specific to the sites in question. Environmental and spatial parameters also seem to impact regulation, so they must be considered during the regulation campaign.

The next step will be to carry out a long-term analysis to re-evaluate the effectiveness of the DOC250 by using a larger number of lethal traps over a more extended trapping period where they are checked every two weeks for instance, to assess the value of deploying them throughout the sea turtles season.

Furthermore, in order to better estimate the effectiveness of the regulation of the small Indian mongoose in protecting sea turtle nests in Martinique, it would be interesting to link the trapping data with the number of nest predations and the egg predation rate on the targeted beaches. In this way, a systematic report of nest predation by mongooses during sea turtle track monitoring campaigns on the beaches in question would be valuable.

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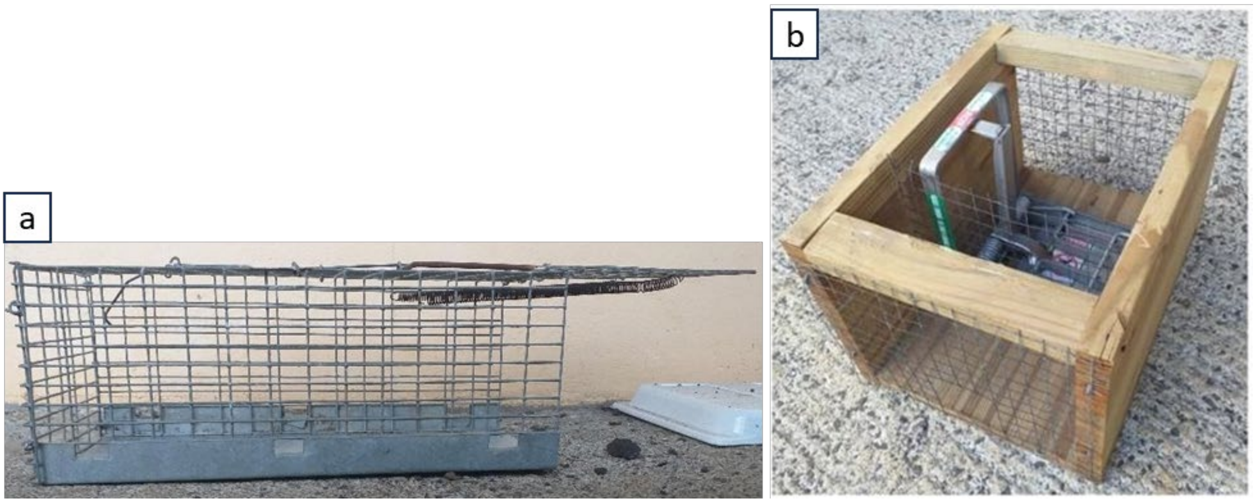
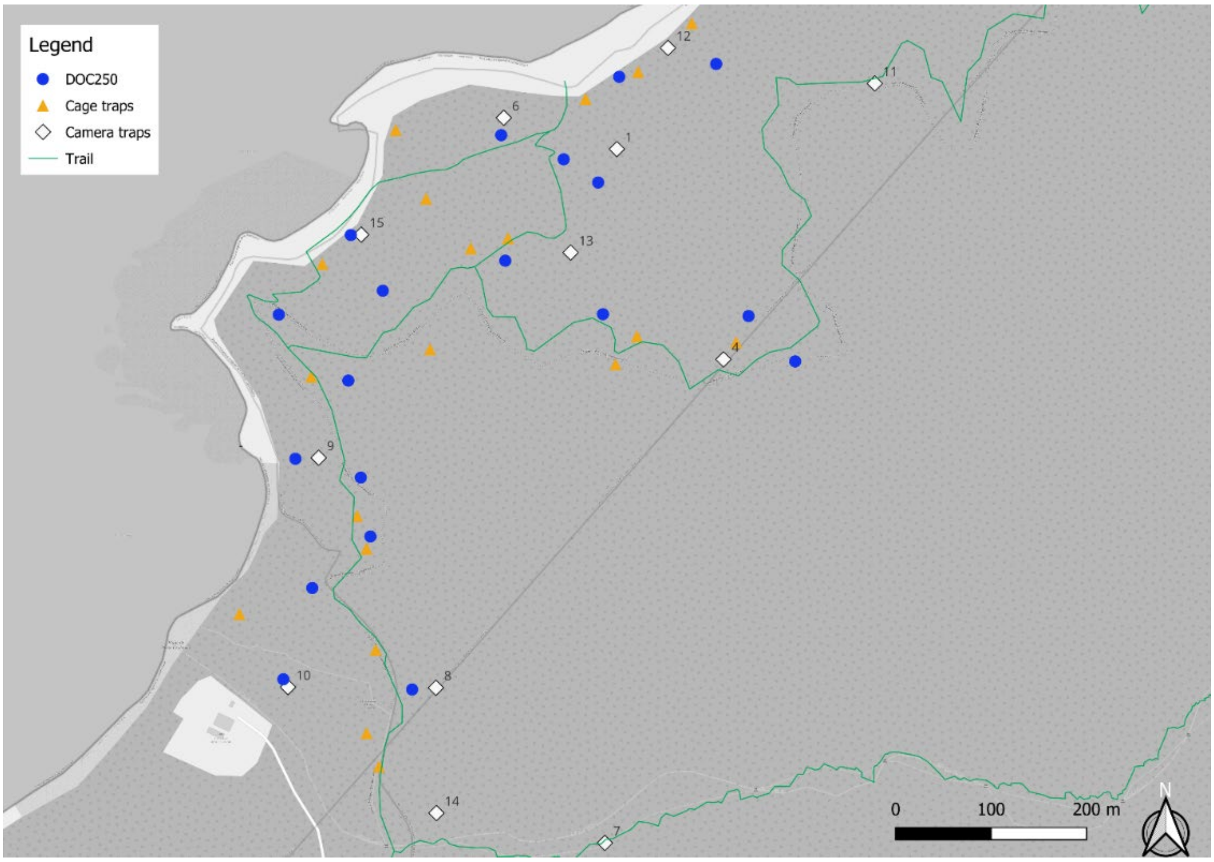
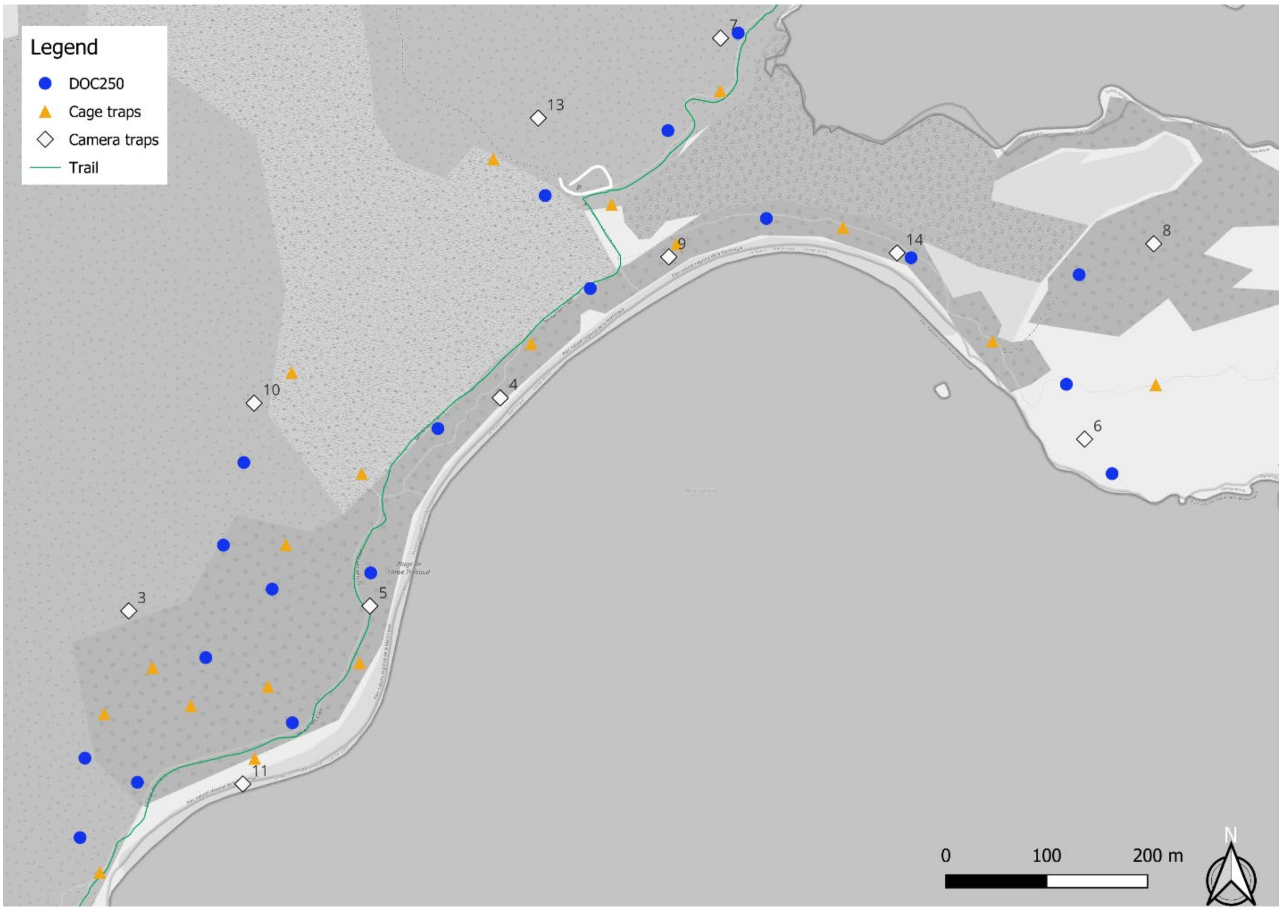
Appendix



Appendix 1. Photos of a Cage Trap open (a) and a DOC250 without the lid (b)



Appendix 2. Map of the distribution of mongoose traps and camera traps on the northern site for the first session. The DOC250 and cage trap positions were reversed for the second session. The numbers shown are the identity (number of the station) of the camera traps.



Appendix 3. Map of the distribution of mongoose traps and camera traps on the southern site for the first session. The positions of the DOC250 and the cage traps were reversed for the second session. The numbers shown are the identity (number of the station) of the camera traps.

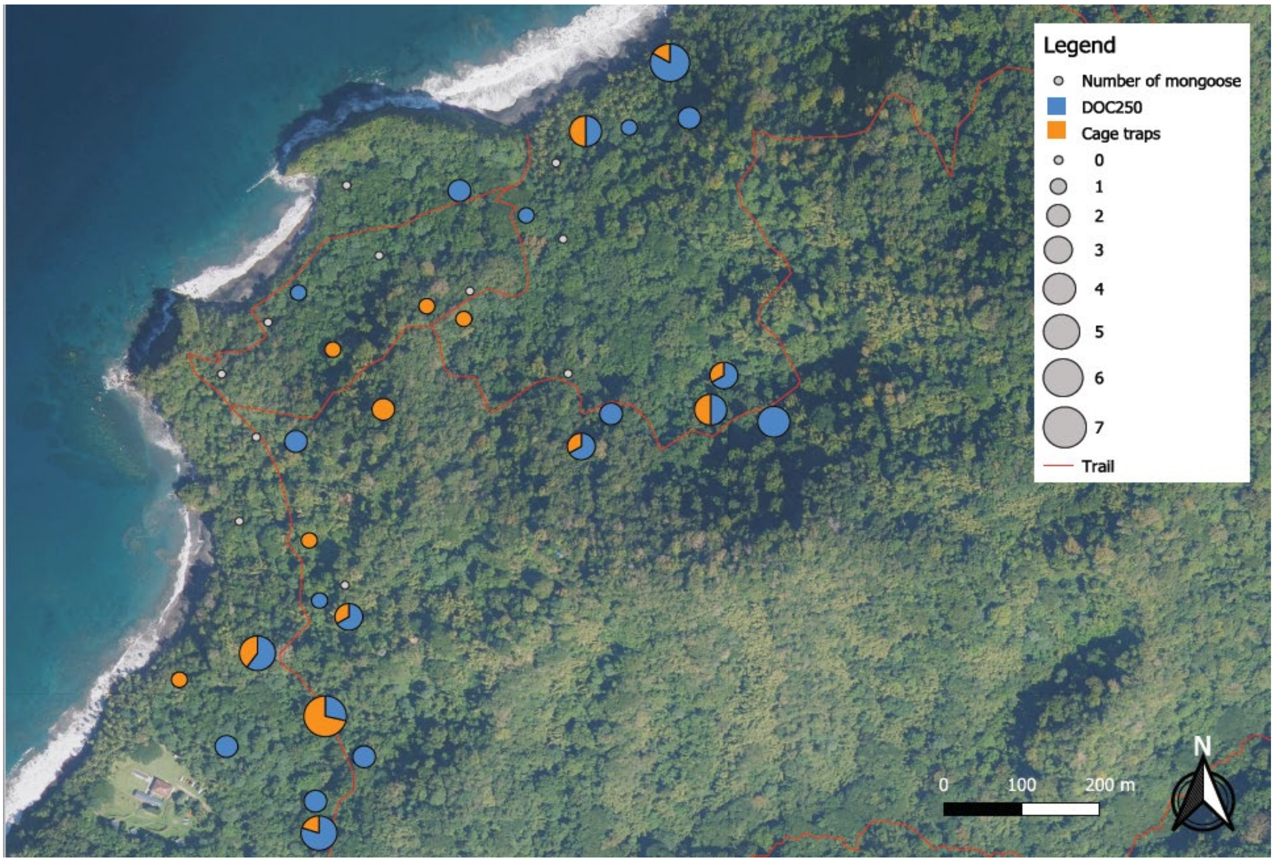
Appendix 4. Photo of camera traps calibration on the field at the northern site

Appendix 5. REM and density equation

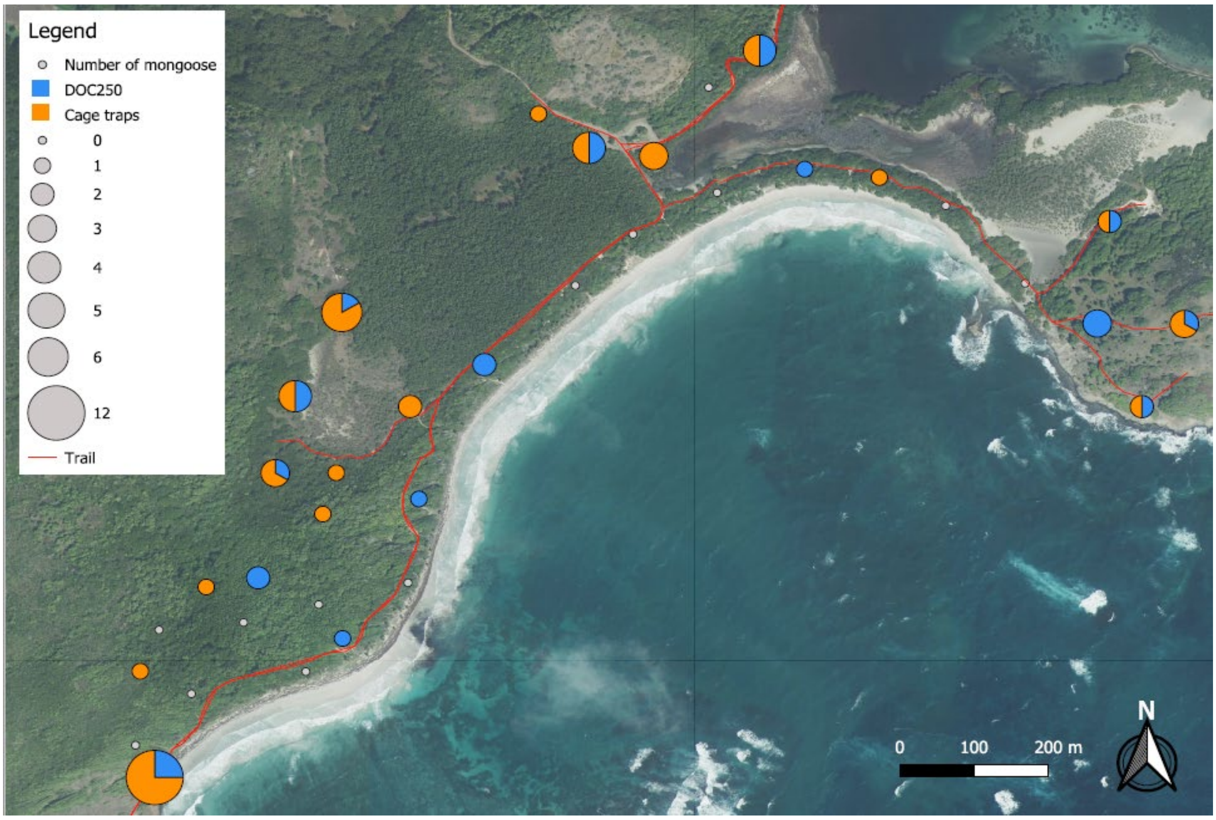
The density is calculated for the collective field of view of the cameras (Gilbert et al., 2020) according to the equation:

$$D = \frac{y}{t} \cdot \frac{\pi}{v \cdot r \cdot (2 + \theta)}$$

Where Y corresponds to the number of detections, t to the total tracking effort, v to the daily distance travelled by an animal in the population, r to the radius (i.e. the detection distance) and θ to the cameras' detection angle, the effort t corresponds to the number of days during which the cameras were active multiplied by the number of active cameras.



Appendix 6. Map showing the number of mongooses caught by trap type on the northern site. The size of the circles represents the number of mongooses caught per trap during the two sessions. The colours represent the type of trap (sessions 1 and 2 mixed).



Appendix 7. Map showing the number of mongooses caught by trap type on the Southern site. The size of the circles represents the number of mongooses caught per trap during the two sessions. The colours represent the type of trap (sessions 1 and 2 mixed).

Appendix 8. Table of the summary of RAI per session for the northern site

Northern site	Effort (in days)	number of observations	RAI=100*(obs/effort)
Before s1	141,02	95,00	67,37
After s1	44,41	9,00	20,27
Before s2	181,09	50,00	27,61
After s2	236,07	55,00	23,30

Appendix 9. Table of the summary of RAI per session for the southern site

Southern site	Effort (in days)	number of observations	RAI=100*(obs/effort)
Before s1	114,54	17,00	14,84
After s1	123,21	17,00	13,80
Before s2	292,43	72,00	24,62
After s2	247,62	43,00	17,37

Abstract

The small Indian mongoose (*Urva auropunctata*) is an introduced predator that poses a significant threat to several species endemic to the islands and endangered species such as marine turtles, by predating on eggs at nesting sites. As part of the National Action Plan for marine turtles in the French West Indies, campaigns to regulate this invasive alien species have been carried out in Martinique by the Office National des Forêts since 2018. This study, conducted during the 2023 control campaign, aims to test the effectiveness of two types of traps (lethal and non-lethal) to establish a rigorous and reproducible protocol for regulating the mongoose. This control campaign occurred at two nesting turtles' sites, one in the north and one in the south of Martinique. Two trapping sessions of 12 days at each of the sites resulted in the killing of 140 mongooses. The results showed that the 2023 campaign was more effective than in other years. We also found greater efficiency in DOC250 to capture mongooses compared to cage traps at the northern site but no difference at the southern site. However, the DOC250 also captured more bycatch at the southern site due to the presence of hermit crabs. The models also suggested that the probability of catching the small Indian mongoose decreased with increasing rainfall. Density and abundance data confirmed that mongoose numbers were lower after a trapping session. This study increases the ecological knowledge of *Urva auropunctata* and suggests improvements for the regulation of this species in Martinique.

Keywords: *Urva auropunctuva*, DOC250, cage traps, camera traps, sea turtle nests predation