A Technical Report for the

ALA PROGRAMME: PHASE II

Fourth Assessment Report of Faunal and Floral Biodiversity in Sainte Luce's Forest Corridors and Littoral Forest

July 2023

Summary

Madagascar's littoral forests face a variety of threats, including unsustainable logging, increased reliance on natural resources, and climate change. The Sainte Luce littoral forest in the Anosy region, southeast Madagascar, is no exception. The Sainte Luce littoral forest supports disconnected populations of four Endangered lemur species, a rich diversity of floral and invertebrate species and numerous amphibian and reptilian species, including nationally endemic and micro-endemic species.

Initiated in 2019, SEED Madagascar's Ala Programme is a ten-year littoral forest conservation strategy. To increase habitat connectivity, the Ala Programme, has planted five forest corridors to connect littoral forest remnants with a larger protected forest fragment, fragment eight (*S8 North)*. Since 2019, SEED's Conservation Research Programme has been conducting ecological monitoring of the forest corridors and littoral forest remnants. Lemur, amphibian, reptile, and invertebrate populations within the corridors and littoral forest remnants have been monitored to gain a detailed understanding of species richness, diversity, and the distribution of spatially disconnected populations. This research was complemented by floral research to monitor Programme progress holistically.

Between October 2022 and May 2024, camera traps were deployed in Littoral Forest Corridors 1 to 4, to monitor lemur movement through the corridors, for a total of 1,563 trapping nights. Monitoring methods were adapted during this period to increase the efficiency and efficacy of camera trap use. While no lemurs have been recorded within the corridors, as of May 2024, there has been one image of *Cheirogaleus thomasi* recorded on the edge of Corridor 3. Additionally, there have been small, non-native mammals and native birds observed in the corridors on the reviewed footage thus far.

Between July 2019 and May 2024, 153 herpetofauna visual encounter surveys were completed in the corridors, with 188 observations of 13 identified species. The most frequently observed species were two species of skink, *Trachylepis elegans* and *Trachylepis gravenhorstii*, and the frog *Heterixalus boettgeri*. Additional herpetofauna species continue to be observed within the corridors. As such, it is important that monitoring continues.

Between August 2019 and May 2024, 54 invertebrate catch-and-release surveys were conducted, with an adjusted total of 7,123 invertebrates observed from 20 known phylogenetic orders made across the corridors and forest remnants. Orthoptera, Arachnida, and Hymenoptera were the most observed orders in the corridor quadrats, while Arachnida, Isoptera, and Blattodea were the most observed orders in the forest remnant quadrats.

Survival and growth of planted flora have been monitored quarterly in four of the Ala Programme's Forest corridors. Additional survival and growth surveys have been conducted monthly in quadrats in all five of the forest corridors. In May 2024, the average height of native seedlings across Corridors 1 to 4 was 18.08cm. As forest corridors become more established and average native tree height, circumference, and canopy cover increase, it is expected that faunal biodiversity within the corridors will increase. *Acacia* are successfully growing in all the forest corridors, increasingly providing shade and structure for the native seedlings in Corridors 1 to 5.

1 Introduction

1.1 Background

Madagascar is one of the world's highest conservation priorities (Myers et al., 2000). As a megadiverse country (Convention on Biological Diversity, n.d.), Madagascar supports around five percent of global biodiversity (Ministry of Environment and Forests Madagascar, 2014) and has some of the highest levels of endemism worldwide (Helmstetter et al., 2021). Forest loss, however, continues to threaten Madagascar's unique flora and fauna, with 4.62 million hectares of forest cover lost through deforestation between 2001 and 2021 (Global Forest Watch, 2023). As a result, lemurs have been categorised as one of the world's most threatened mammal groups (IUCN, 2020), with habitat loss and fragmentation threatening populations across the country (Schwitzer et al., 2013).

1.2 Littoral Forests

Littoral forest ecosystems are one of the most threatened ecosystems in Madagascar (Watson et al., 2010) and are considered a national conservation priority (Ganzhorn et al., 2001). Habitat fragmentation and degradation continue to endanger this ecosystem and the myriad of genetically diverse species it supports (Consiglio et al., 2006; Krishnan et al., 2013). The Anosy region in southeast Madagascar contains some of the few remaining viable littoral forests, including the Sainte Luce littoral forest (SLLF). Littoral forests support unusually rich and diverse ecological communities (Bollen & Donati, 2006), including 13% of the country's native flora (Consiglio et al., 2006). The SLLF is one of three larger littoral forests left in the region, comprising 17 fragments, and supporting a large variety of plant species, 83% of which are endemic to Madagascar (Rabenantoandro et al., 2007). Additionally, the SLLF is home to populations of various Threatened species, such as four Endangered lemur species: the Red-collared brown lemur (*Eulemur collaris*), the Southern woolly lemur (*Avahi meridionalis*), the Anosy mouse lemur (*Microcebus tanosi*), and the Thomas' dwarf lemur (*Cheirogaleus thomasi*) (Donati et al., 2020a; Donati et al., 2020b; Donati et al., 2020c; J. Ganzhorn et al., 2020).

The SLLF supports a highly impoverished and growing community (SEED Madagascar, 2021) who depend on the forests for natural resources (Bollen & Donati, 2006) however, the SLLF is threatened by a variety of factors. Irregular rainfall and frequent droughts have depleted groundwater sources (Ashraf et al., 2021), exacerbating edge effects[1] and increasing vulnerability to fire (Cochrane & Laurance, 2002). The SLLF fragments are especially vulnerable because they have dry, fire-prone edges which are predominantly adjoined to grasslands that are often burned as part of a traditional land management technique called *tavy*[2] (Cochrane & Laurance, 2002; Schwitzer et al., 2013). In addition to community use, proposed mining operations by QIT Madagascar Minerals (QMM) threaten to remove 661.80ha of the SLLF, increasing the risk of extinction of locally endemic species (Bollen & Donati, 2006; Temple et al., 2012; Watson et al., 2010).

1.3 The Ala Programme

As a response to the threats facing the SLLF, SEED Madagascar (SEED) initiated the Ala Programme (*ala* meaning forest in Malagasy), a ten-year littoral forest conservation strategy. The Programme aims to improve habitat connectivity and species dispersal between SLLF Fragment 8 (S8) and nearby forest remnants (R1, R2, R3, R4) through the creation of five forest corridors (C1, C2, C3, C4, C5). In Phase I (2019-2021), SEED planted four forest corridors with *Acacia mangium* (*Acacia*) and native seedlings, totalling 1.64ha. In Phase II (2021-2024), available habitat was increased by expanding the original corridors and establishing a fifth forest corridor, creating a total corridor area of 3.72ha and connecting 111ha of littoral forest. Phase II aimed to understand and meet

[1] Edge effect involves microclimatic variations (light, temperature, and humidity) in the forest edge that become unsuitable for organisms adapted to forest interior conditions (Aragón et al., 2015).

[2] *Tavy* is a swidden agricultural practice which involves setting intentional fires to clear land for agriculture.

community forest resource needs, build sustainable, locally led forest management structures, and contribute to the body of international conservation knowledge regarding forest corridors as a conservation strategy.

Forest corridors facilitate the movement of forest-dependent species between patches of otherwise disconnected habitat. This has been found to increase habitat connectivity and permeability (Andriamandimbiarisoa et al., 2015; Caro et al., 2009; Christie & Knowles, 2015) and mitigate the effects of habitat fragmentation (Christie & Knowles, 2015). Forest corridors can increase gene flow between previously disconnected habitats, supporting larger population sizes (Caro et al., 2009; Pardini et al., 2005; Wan et al., 2018).

Through the establishment of forest corridors, the Ala Programme aims to increase and improve habitat connectivity for the conservation of three Endangered nocturnal lemur species (*Avahi meridionalis*, *Cheirogaleus thomasi*, and *Microcebus tanosi*) which cannot traverse the open land created by fragmentation. The Programme will also conserve and study many invertebrate and herpetofauna species in the SLLF, including the Critically Endangered *Guibemantis diphonus* (frog) (IUCN SSC Amphibian Specialist Group, 2020) and the Critically Endangered *Phelsuma antanosy* (gecko) (Jenkins et al., 2011a).

A large proportion of the S8 and surrounding forest remnants one to four (R1, R2, R3, R4) were designated as a community protected area as part of QMM's mining offset zone (Temple et al., 2012). These areas are part of Madagascar's National Protected Areas network, classified as conservation zones under IUCN Category V Protected Areas regime, and provide crucial lemur habitat. *Avahi meridionali*s have been recorded in the forest remnants surrounding S8, making it imperative to connect R1-R4 to S8 to reduce the risk of inbreeding and other detrimental consequences of isolation. Increasing forest remnant habitat availability may also be crucial for the protection of *Eulemur collaris,* by providing additional suitable habitat. Moreover, an increase in local lemur populations will increase native seed dispersal, which will in turn improve chances of long-term survival for the forest itself.

2 Methodology

Data collected since the beginning of the Ala Programme, in April 2019, have yielded a variety of interesting and important observations. From March 2020, in-situ capacity was reduced due to the COVID-19 pandemic, as a result not all lemur, herpetofauna, and invertebrate surveys were completed as scheduled. Data collection resumed at a normal frequency from January 2022.

2.1 Study Site

The Ala Programme conducts research in five forest corridors between forest fragments in the rural community of Sainte Luce, southeast Madagascar (24° 46' S, 47° 10' E) (Figure 1). The five corridors cover 3.72ha and connect a total area of 111ha of littoral forest. Data collection is led by SEED's Conservation Research Programme (SCRP) and started in May 2019, following the planting of C1 to C4. C5 was planted in April 2022; floral monitoring is ongoing here, and faunal monitoring will start once the corridor vegetation is more established, in Phase III.

2.2 Data Collection

Three methodologies have been used for assessing faunal biodiversity within C1 to C4, Visual Encounter Sampling (VES), catch-and-release sampling, and camera trapping. Additionally, survival and growth quadrat surveys have been conducted in C1 to C5 to assess floral biodiversity. This report summarises the findings of data collected by the Ala Programme over the last five years, from May 2019 until May 2024, with particular focus on the last technical year (June 2023 to May 2024).

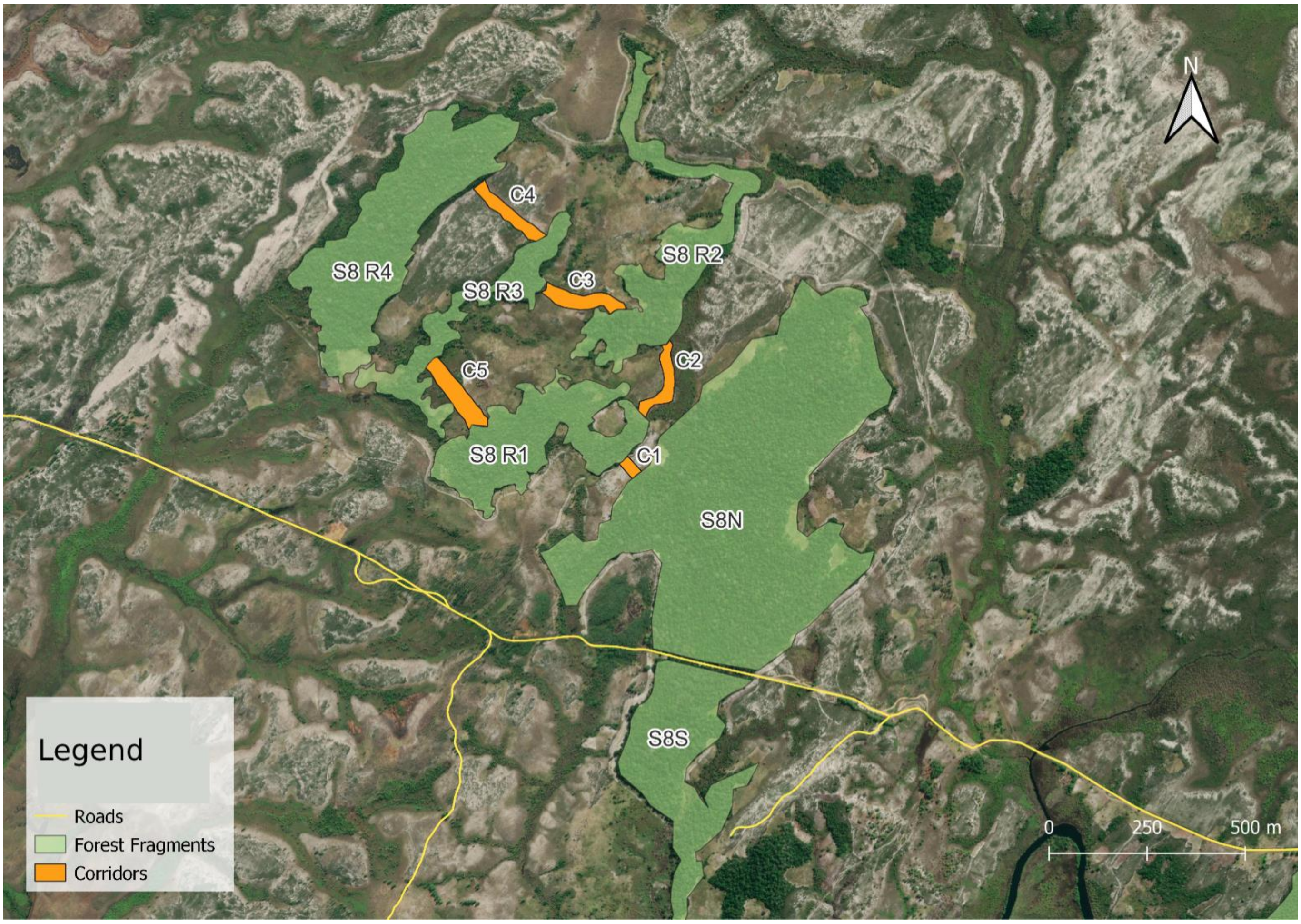

Figure 1: The Ala Programme study site.

2.2.1 Lemurs

Lemur Visual Encounter Surveys (VES) were carried out in the corridors between May 2019 and October 2022. From this point on, lemur populations have been surveyed using camera traps. The methodology for lemur VES can be found in the Ala Programme: Phase II Technical Report – 2023.

2.2.1.1 Camera Trapping

Pilot camera trapping trials were conducted between October 2022 and January 2023. The results from this trial can be found in the Ala Programme: Phase II Technical Report 2023. From April 2023, two cameras were placed in C1 to C4, one in the middle and one near the remnant edge. This was done after obtaining permission from the corridor landowners.

In October 2023, a third camera was installed in corridors 1 to 4 at the edge that did not already have a camera, bringing the total number of camera traps deployed to 12. Camera trapping coverage will increase in Phase III with the installation of additional camera traps in C5. The aim of adding additional cameras was to capture any potential lemur interaction with corridor edges from the forest remnants or S8 fragment while maintaining capacity for identifying lemurs travelling through the corridors. Each camera takes three-photo bursts, which, compared to other settings, reduces the blur of an animal moving across the frame, and allows for the images to be more easily reviewed by researchers. Camera traps were situated to face either the north or the south to reduce the direct glare of the rising or setting sun and reduce the likelihood of the infrared detector being triggered by the sun reflecting off leaves. The cameras were placed on the trees at an angle that captures as much of the upper reaches of the trees as possible since the target nocturnal lemurs are arboreal and would move through the dense leafy canopy. Care was taken to attach the cameras to trees with sparse branch cover around the camera and to remove any overhanging branches surrounding the camera to reduce the likelihood of non-target trigger events.

Camera batteries and SD cards were checked roughly every ten days and changed if necessary. When the batteries or SD cards were changed, there would be a period of one to two days where the cameras were not operational. Once the footage was downloaded, it was reviewed by research staff and volunteers. Images containing no meaningful information were deleted (i.e. no wildlife).

2.2.2 Herpetofauna Visual Encounter Sampling

Under the Ala Programme, SCRP recorded all observations of herpetofauna species along a set transect (Hutchens & Deperno, 2009). Transects were established through the centre of the corridor in C1 to C4. Surveys took place in each corridor once every three months, with one survey conducted during the day for diurnal species and one at night for nocturnal species.

VES are a way of systematically monitoring an area with standardised effort that is often used to estimate population densities from long-term datasets (Flint & Harris, 2005; Furnas et al., 2019). Herpetofauna diurnal and nocturnal VES were conducted at the appropriate times of day by at least one experienced SCRP staff member and a local expert guide, who moved along each transect at a slow speed (~1km/hr). Torches were used to aid detection during nocturnal surveys. Prior to each survey, contextual data were recorded. When an observation was made, environmental and biological variables were recorded, including time of sighting, species sighted, life stage (juvenile, sub-adult, or adult), GPS coordinates of sighting location, distance from transect (m), height of individual, microhabitat (such as in the leaf litter, under a dead branch, on a tree trunk), and any additional information of interest. If the perch (e.g. tree) was too tall to be measured using a measuring tape, a visual estimate was made and agreed on by the researchers present.

2.2.3 Invertebrate Catch-and-Release Surveys

Invertebrate catch-and-release surveys were conducted in 20, 10mx10m longitudinal quadrats situated in C1 to C4, R1 to R4, and S8. Five quadrats were created, one in the centre and two at the edges of each corridor, and then two in the adjoining forest remnants. The quadrats within the forest remnants serve as ecological baselines that corridor invertebrate biodiversity could be compared to.

Each quadrat was surveyed for ten minutes to monitor invertebrate presence and abundance. Three to five SCRP data collectors conducted each survey. Contextual data were recorded prior to the survey, including date, start and finish time, number of observers (staff and volunteers), weather, and percentage cloud cover. Oftentimes, species could only be identified to order, as many species in the SLLF are undescribed. A photographic guide sheet of the different species previously observed by SCRP was used to aid identification, standardise observations, and identify potential new species. A morphological species (morpho-species) code was assigned to each species in the identification guide (e.g., arach3). The code was recorded on the datasheet with a tally made for every time an individual of that species was caught. If a species was absent from the identification guide, it was recorded as a new species and identified to order level. New species were photographed with scale and described so that they could be identified and added to the guide (e.g. size, distinct features, antennae length). Once identification was complete, every individual was released outside the quadrat to prevent repeated sampling. Handling time was kept to a minimum to reduce stress for the captured individual.

2.2.4 Additional Opportunistic Sightings

Opportunistic sightings of species are recorded outside of scheduled surveys or specific data collection periods if the species is not seen frequently in the corridors. In such incidents, the species name, number of individuals, sex (if identifiable), location, and date are recorded. Such sightings are particularly helpful in identifying individuals that are not observed by camera traps or within herpetofauna or invertebrate surveys. Opportunistic observations are not included in data analysis but are noted in this report as they contribute to the understanding of species diversity within the corridors.

2.2.5 Survival and Growth

2.2.5.1 Quarterly Monitoring

Survival and growth data of *Acacia* and native species were recorded for seedlings within monitoring quadrats. Since the Ala Programme's corridors were planted at different times, the date of the first data collection within quadrats differed for each forest corridor (Annex 1). Survival and growth data were collected for SCRP-monitored seedlings within fixed quadrats in C1 to C4. There are two quadrats per corridor, one at the edge and one in the middle, all measuring 10mx10m. All quadrats were visited during daylight hours, with data for survival and growth collected at the same time. General data were recorded, such as quadrat code, seedling identification number, species, and other abiotic factors such as weather and rainfall. Seedling survival was monitored using their condition, which was rated from 1 to 4 (Annex 2) and was recorded through visual cues, such as if the seedlings were alive or dead, wilting, or had lost leaves. Mean seedling growth over time was calculated by measuring height from the root collar to the apex with a tape measure.

Native seedling survival and growth measurements were collected at initial planting, and at months one, three, six, nine and 12 after planting. Following this, survival and growth data continued to be collected every three months.

Acacia seedling survival and growth measurements were collected at initial planting, and at months one, three, six, and 12 after planting, following this they were monitored once a year. Additionally, growth for *Acacia* was calculated using the height and Diameter at Breast Height (DBH). The DBH was measured at the middle of the trunk for seedlings <1.30m and at breast height for seedlings ≥1.30m in height (Batcheler, 1985). If the *Acacia* became too tall to be measured using the tape measure, their height was visually estimated. The *Acacia* are now deemed well-established, and as such, *Acacia* monitoring was concluded at the end of 2023.

2.2.5.2 Monthly Monitoring

Additional fixed monitoring quadrats for native seedlings were set up in C1 to C4 in July 2023. A fifth monitoring quadrat was established in C5 in March 2024, after native seedlings were planted in February 2024 (Annex 1). Monitoring quadrats, measuring 9mx9m were established after corridors had been planted, and as such, the number of seedlings monitored in each quadrat varies depending on the corridor. Quadrat locations were randomly chosen, however, there was selection bias for areas with a high number of living seedlings. Survival and growth data was recorded monthly from quadrat establishment.

All quadrats were visited during daylight hours, with data for survival and growth collected at the same time. Seedling condition was rated from 1 to 4 (Annex 2) and was recorded through visual cues, such as, if the seedlings were alive or dead, wilting, or had lost leaves.

3 Results

3.1 Lemurs and other Mammals

3.1.1 Lemurs

In November 2022, a camera trap at the edge of C3 captured an image of a *C. thomasi* in the adjoining forest remnant (Figure 2). After the pilot study, camera traps were deployed for monitoring. Since full deployment in January 2023, a total of 1,563 nights of footage have been collected. Footage captured throughout 2023 has been reviewed, no further lemur sightings have been made in the footage analysed during this time. Camera trap footage from 2024 is currently being reviewed.

In April 2023, a group of four *E. collaris,* two males and two females, were opportunistically observed in C1 moving towards R1. Additionally, there was an opportunistic sighting of *C. thomasi* eyeshine in R1 around C1 in November 2023.

Figure 2: Image of a C. thomasi from a camera trap on the edge of C3, November 2022.

3.1.2 Other Mammals

In April 2022, one *Fossa fossana* (Spotted Fanaloka) was opportunistically observed on the edge of C2, near a wetland that borders the corridor. Since January 2023, there have been five observations of non-lemur mammals in the corridors on the camera traps (Figure 3), four of *Rattus rattus* (black rat) in C3 (middle and edge), and one of a *Viverricula indica* (small Indian civet) in C4 (edge).

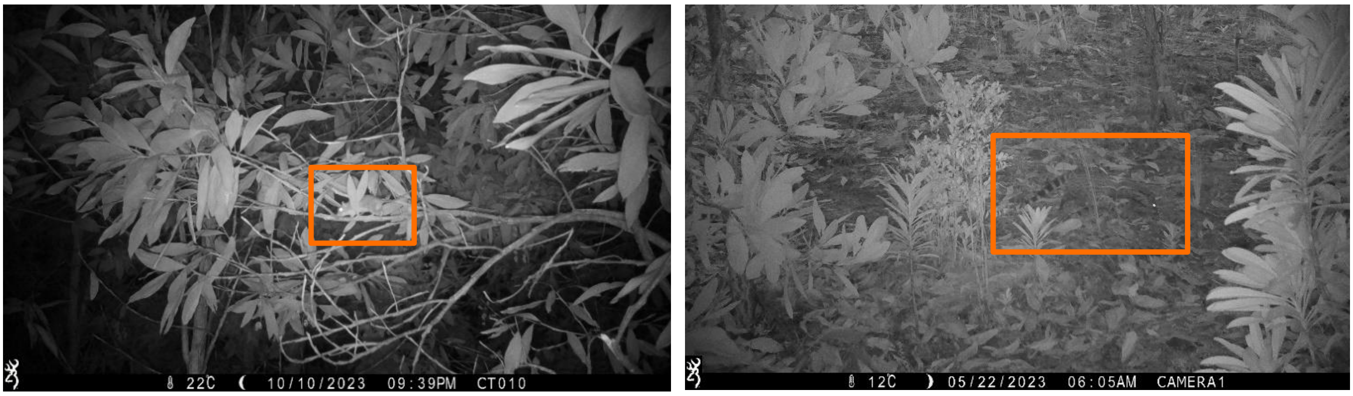

*Figure 3: Left – black rat (*Rattus rattus*) in C3, right – Indian civet (*Viverricula indica*) in C4. The orange boxes highlight the two mammals.*

3.2 Herpetofauna

Between July 2019 and May 2024, 153 herpetofauna biodiversity surveys were completed in the forest corridors (75 diurnal and 78 nocturnal surveys). There were 48 surveys conducted during this time where no herpetofauna were observed. There have been 320 observations of 15 identified species across the four monitored corridors; C4 had the highest number of herpetofauna observations (n=95), followed closely by C3 (n=93) and C2 (n=84), C1 had fewer numbers of herpetofauna observed (n=48).

The most frequently observed species in the corridors were skinks, *Trachylepis elegans* (n=114) and *Trachylepis gravenhorstii* (n=45), as well as a reed frog, *Heterixalus boettgeri* (n=48) (Figure 4). The species richness[3] (S) was highest in C3, where there were ten different species of herpetofauna observed. The species richness was lowest in C1 (S=6). To date, *Acrantophis dumerili* and *Dromicodryas bernieri* have only been observed in C2; *Calumma sp. aff. nasutum*, *Ithycyphus oursi*, *Madagascarophis meriodionalis,* and *Phelsuma lineata* have only been observed in C3. *Mimophis mahfalensis* and *Ptychadena mascariensis* have only been observed in C4 (Figure 4).

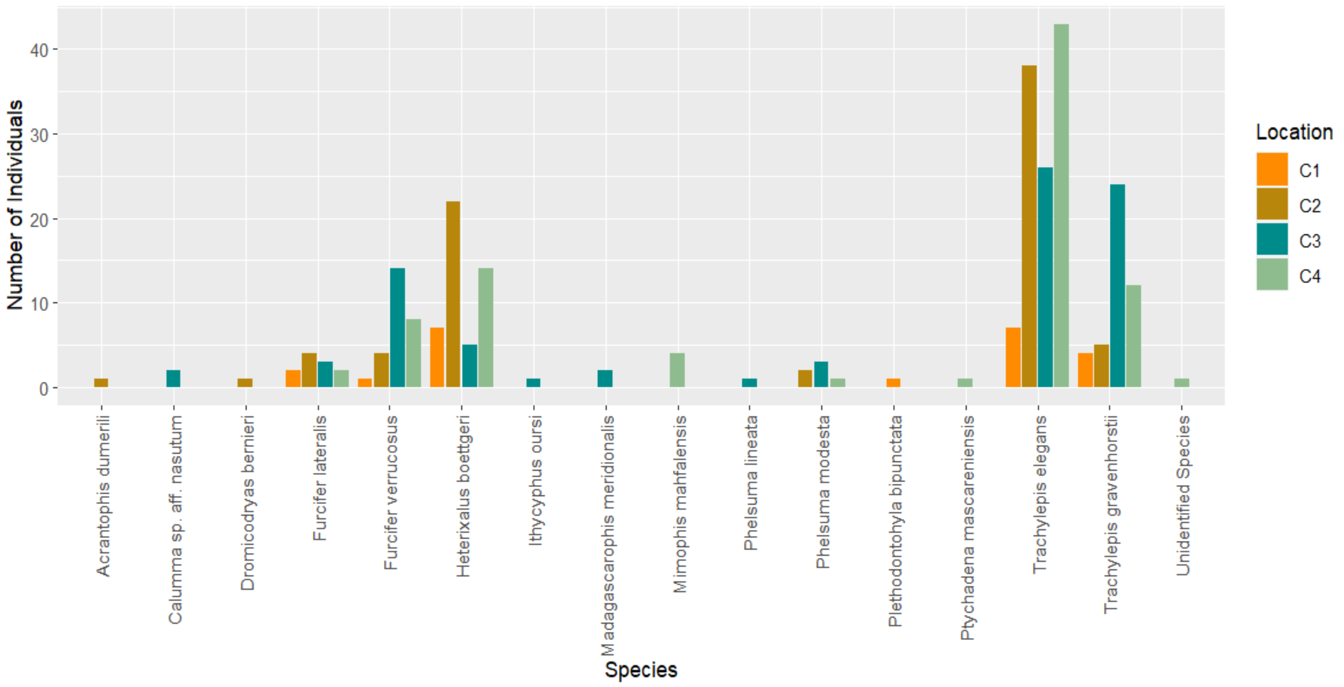

Figure 4: Herpetofauna species observed within the C1 to C4, between July 2019 and May 2024.

The discovery rates of new herpetofauna species within C2, C3, and C4 have steadily increased over time, with C3 having the highest discovery rate (Figure 5). The rate of discovery of new species is lowest in C1, where there were no herpetofauna species observed during the first six surveys or between the ninth and 30th surveys. During the last technical year (June 2023 to May 2024), there were 35 observations of eight herpetofauna species, fewer than the previous technical year (83 observations of ten species) (June 2022 to May 2023). During the last technical year, a day gecko, *Phelsuma modesta,* was observed in C2 and C4 for the first time, and a frog, *Plethodontohyla bipunctata*, was seen in C1 for the first time.

[3] Species richness is the number of species in an area (Moore, 2013).

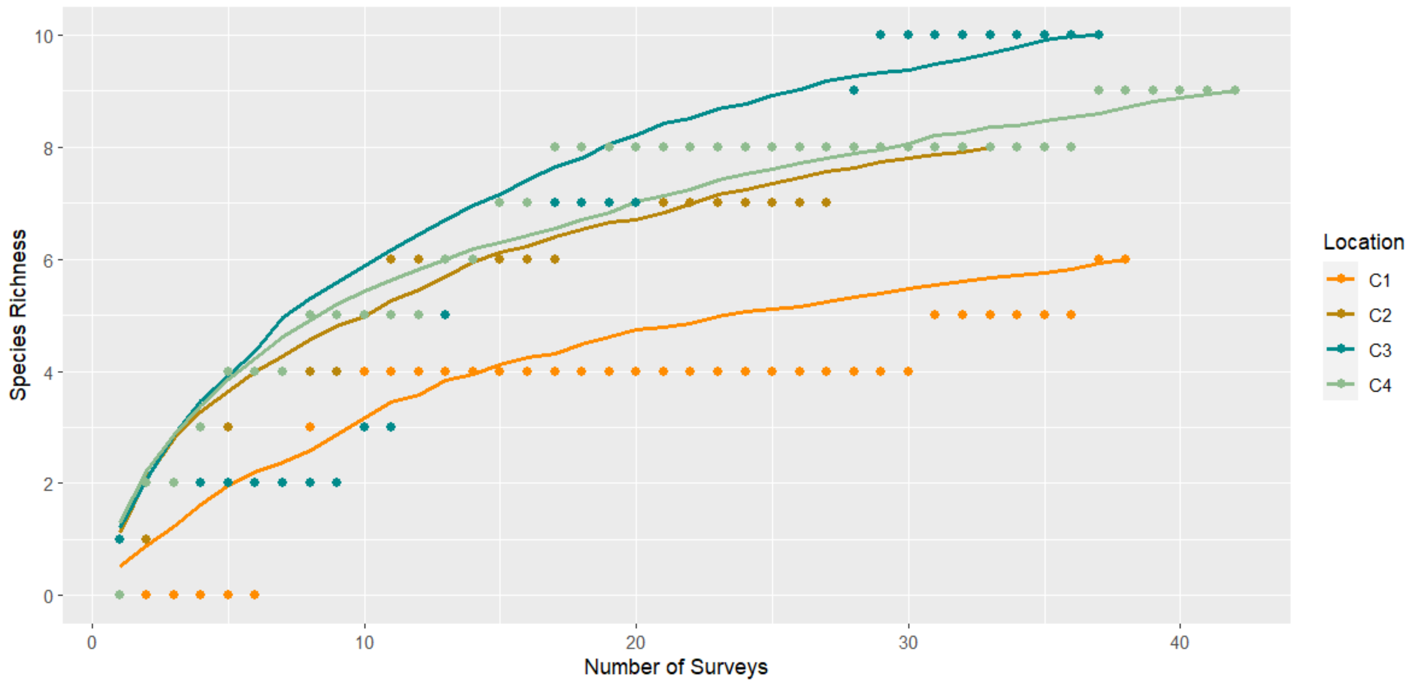

Figure 5: Species Accumulation Curves (SACs) of the number of additional species recorded in each corridor with each survey, this was calculated using a random addition of each survey. The points show the accumulated number of species observed in each Corridor as they occurred over time.

A suite of habitat data was also collected for each observation. On average, observations were made 2.09m from the transect in the corridors and 33.24cm off the ground. All observations of herpetofauna in the forest corridors occurred in the corridor, in dry forest, or on open ground. Overall, herpetofauna were observed in 15 different settings including leaf litter, on and inside wood structures (e.g. trees, tree holes, dead wood, and branches), in swamps and water, and on *Acacia*.

During the last technical year, herpetofauna were observed on the camera traps for the first time. There were four observations of herpetofauna on the camera traps installed in each of the forest corridors (Figure 6), with a species of day gecko, *Phelsuma modesta,* observed on *Acacia* in C2 and C3, and an unknown species of gecko observed in C3 (Annex 2). It was noted that *P. modesta* were observed between camera traps and the *Acacia* trunk when observers were taking them down between research periods.

Figure 6: Camera trap image of P. modesta *seen on* Acacia *trunk. The orange box highlights the gecko on the tree.*

3.3 Invertebrates

Between August 2019 and May 2024, 54 invertebrate biodiversity surveys were conducted. Across all study locations (quadrats in C1 to C4, R1 to R4, and S8N), an adjusted total[4] of 7,123 invertebrates of 20 known orders were observed. The highest number of invertebrates was observed in C1 and the adjoining forest remnants (adjusted n=2,191), with the fewest observations made within C2 and the adjoining remnants (adjusted n=1,413.5).

An *encounter* is when a specific morpho-species is observed in a quadrat during a single survey. The most frequently encountered order in both the forest corridors and remnants was Orthoptera (grasshoppers and crickets) (n=636), followed by Arachnida (spiders and scorpions) (n=626). The most frequently encountered order within the corridor quadrats was Orthoptera (n=569), followed by Arachnida (n=280), whereas the most frequently encountered order in the forest quadrats was Arachnida (n=352), followed by Blattodea (cockroaches) (n=148) (Figure 7).

[4] This is the number of invertebrates adjusted for the difference in the number of quadrats found in the forest and corridor quadrats. As there were two quadrats in the forest, compared with three quadrats in the corridor, the adjusted numbers were calculated by multiplying the number of invertebrates by 1.5.

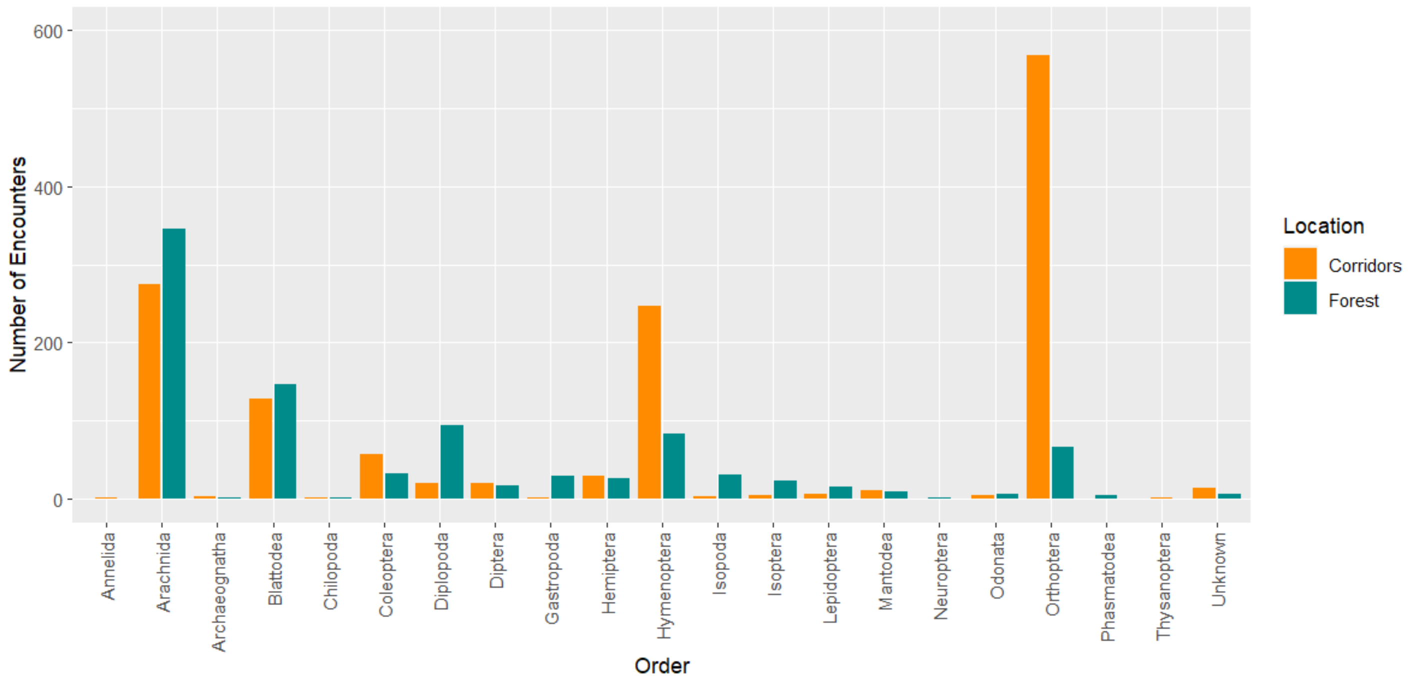

Figure 7: The number of encounters of each invertebrate order within C1 to C4, R1 to R4, and S8N between August 2019 and May 2024.

Within the Ala Programme's Forest corridors, an adjusted 3,248 invertebrates of 19 orders were observed, and an adjusted 3,900 invertebrates of 19 orders were observed within the forest remnants (Table 1Figure 8: Adjusted number of invertebrates of each order observed within C1 to C4, R1 to R4, and S8N between August 2019 and May 2024. It should be noted that the number of invertebrates observed in the forest remnant quadrats was multiplied by 1.5, accounting for the fewer number of quadrats in the forest remnants compared to the forest corridors.). Of these observations, 215 morpho-species were identified, with a number of other species yet to be identified. Arachnida were the most species-rich order (S=64). Corridors and forest remnants were also rich in Orthoptera (S=46), Coleoptera (S=22) and Hymenoptera (S=17). Hymenoptera were the most commonly observed order in the corridors (adjusted n=1,389), followed by Orthoptera (adjusted n=1,002) and Arachnida (adjusted n=381) (Figure 8).

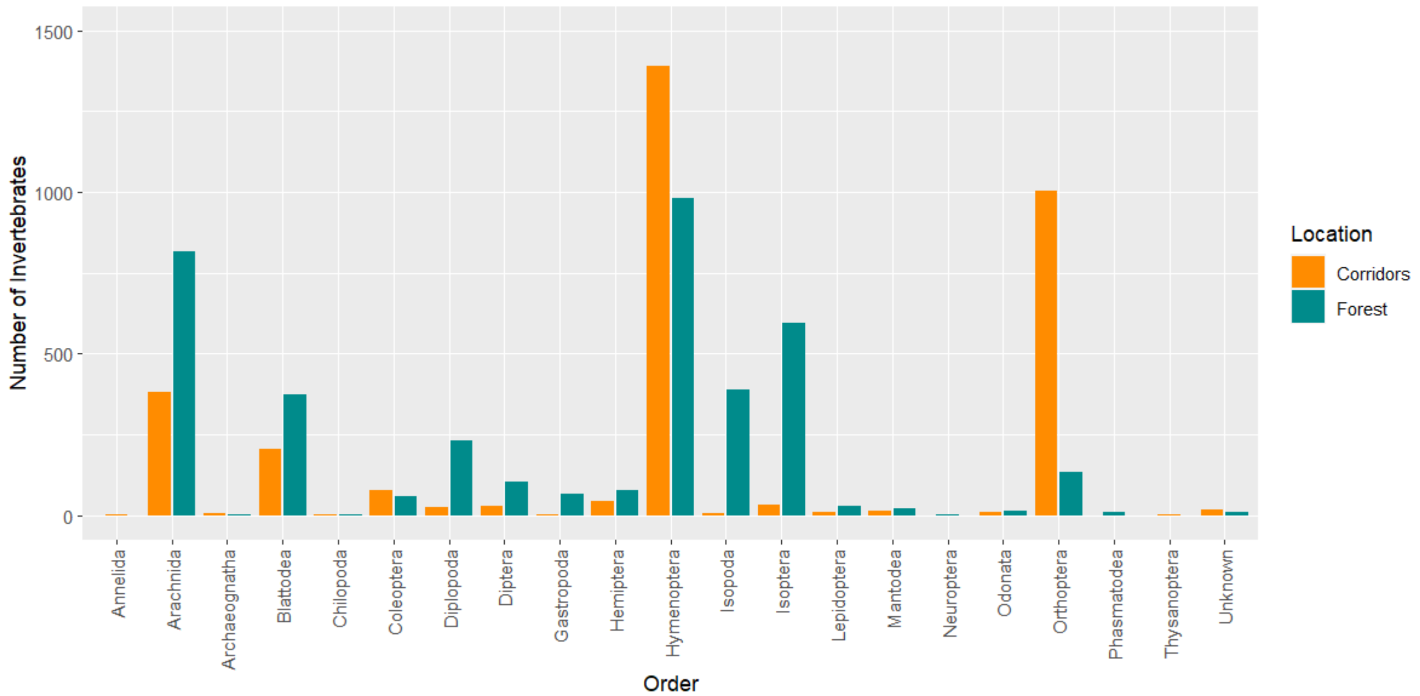

Figure 8: Adjusted number of invertebrates of each order observed within C1 to C4, R1 to R4, and S8N between August 2019 and May 2024. It should be noted that the number of invertebrates observed in the forest remnant quadrats was multiplied by 1.5, accounting for the fewer number of quadrats in the forest remnants compared to the forest corridors.

Table 1: Numbers of invertebrates observed within each order within C1 to C4, R1 to R4, and S8N between August 2019 and May 2024. It should be noted that the number of invertebrates observed in the forest remnant quadrats was multiplied by 1.5, accounting for the fewer number of quadrats in the forest remnants compared to the forest corridors.

Order	Number of Invertebrates in Forest Corridors	Percentage of Order found in Forest Corridors (%)	Number of Invertebrates in Forest Remnants	Percentage of Order found in Forest Remnants (%)
Annelida	2	100	0	0
Arachnida	381	31.9	814.5	68.1
Archaeognatha	6	80	1.5	20
Blattodea	203	35.2	373.5	64.8
Chilopoda	1	40	1.5	60
Coleoptera	78	57.8	57	42.2
Diplopoda	25	9.8	231	90.2
Diptera	27	20.9	102	79.1
Gastropoda	1	1.5	64.5	98.5
Hemiptera	45	37	76.5	63
Hymenoptera	1,389	58.6	979.5	41.3
Isopoda	6	1.5	388.5	98.5
Isoptera	32	5.1	594	94.9
Lepidoptera	9	25	27	75
Mantodea	13	36.6	22.5	63.4
Neuroptera	0	0	3	100
Odonata	9	40	13.5	60
Orthoptera	1,002	98.7	132	1.3
Phasmatodea	0	0	9	100
Thysanoptera	3	100	0	0
Unknown	16	64	9	36
Total	**3,248**		**3,900**	

A Jaccard Similarity Test[5], run using the 'vegan' package in R, assessed the similarity in invertebrate species richness and abundance between quadrats in C1 to C4 and forest remnants. This technical year, C1 had the highest similarity between invertebrate morpho-species found in the corridors and forest remnants (Jaccard Similarity Index value=0.843), while C3 had the lowest similarity (Jaccard Similarity Index value=0.672). There have been no changes in the average similarity between the invertebrate morpho-species found in the forest corridors and remnants (Figure 9).

[5] A Jaccard Similarity Index value of 0 indicates that the two groups are completely different and have no species in common, whilst an index value of 1 indicates that the two groups are identical.

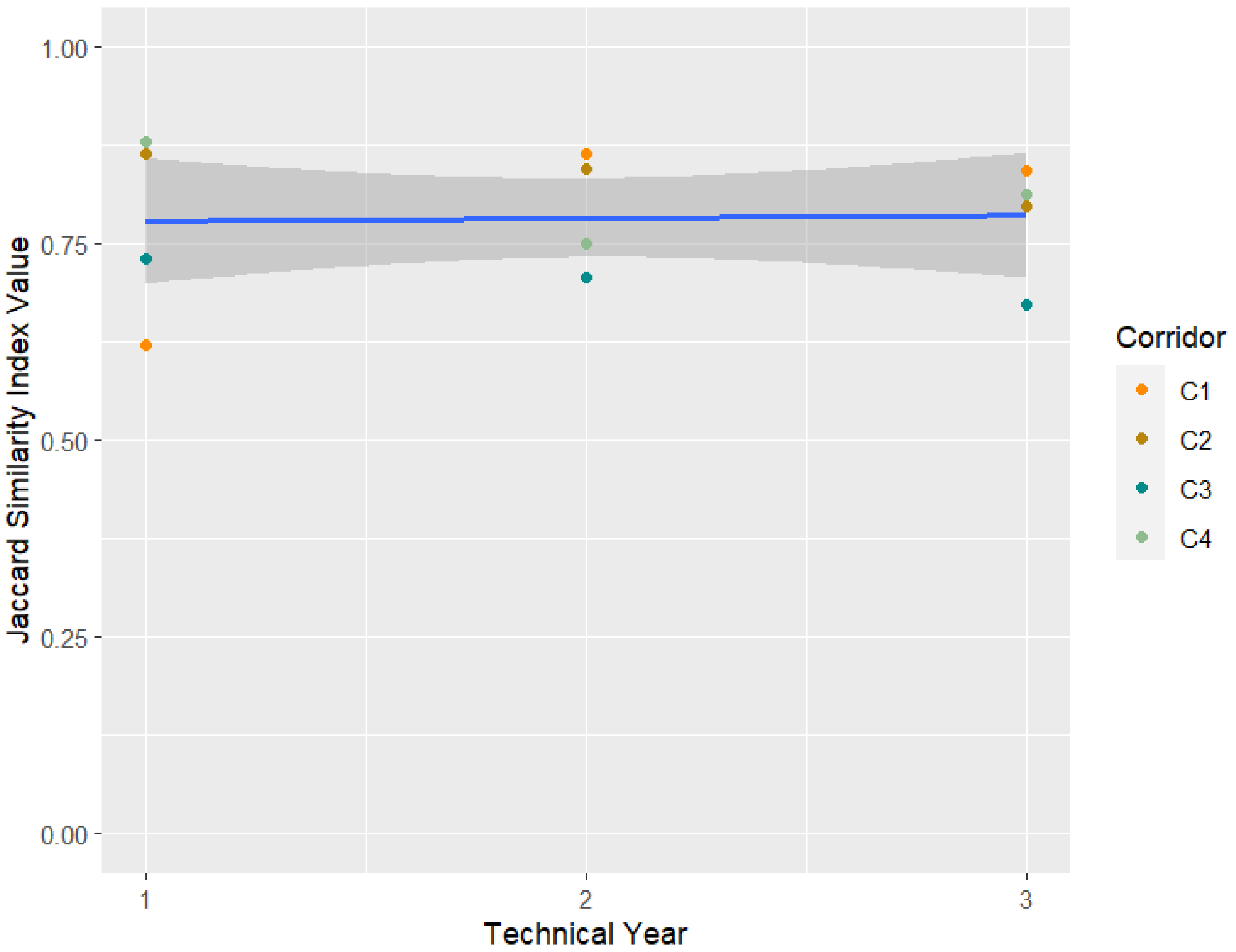

Figure 9: Level of similarity in invertebrate species richness and abundance between the quadrats in the forest corridors and forest remnants, and how this changed over time in each of the Corridors during Phase II. A Jaccard Similarity Test was used to assess the similarity between the invertebrate communities. The line was created using a Generalised Linear Model and the shaded area represents the 95% confidence interval.

New morpho-species of invertebrate continue to be observed in each of the four corridors, with additional morpho-species categorised and added to the Invertebrate Guide that is used to identify the different morpho-species. This technical year, 46 morpho-species were categorised and added to the Invertebrate Guide.

3.4 Birds

In July 2023, there were guineafowl (*Numida melagris*) captured on footage in C1, a Madagascar long-eared owl (*Asio madagascariensis*), an unknown bird in C3, and a Souimanga sunbird (*Cinnyris sovimanga*) in C4 (Figure 10).

*Figure 10: From top left – Guinea fowl (*Numida melagris*) in C1, the orange boxes highlight the birds, Madagascar long-eared owl (*Asio madagascariensis*) in C3, unknown bird in C3, Souimanga sunbird (*Cinnyris sovimanga*) in C4.*

3.5 Botanical Biodiversity

3.5.1 *Acacia* Survival and Growth

At the most recent point of data collection, in July and August 2023, the *Acacia* were tallest in C3, both at the edge of the corridor and in the middle (Figure 11). The *Acacia* in C2 were the shortest both at the edge and in the middle of the corridor, however, they were planted most recently, in July 2020 (Annex 1).

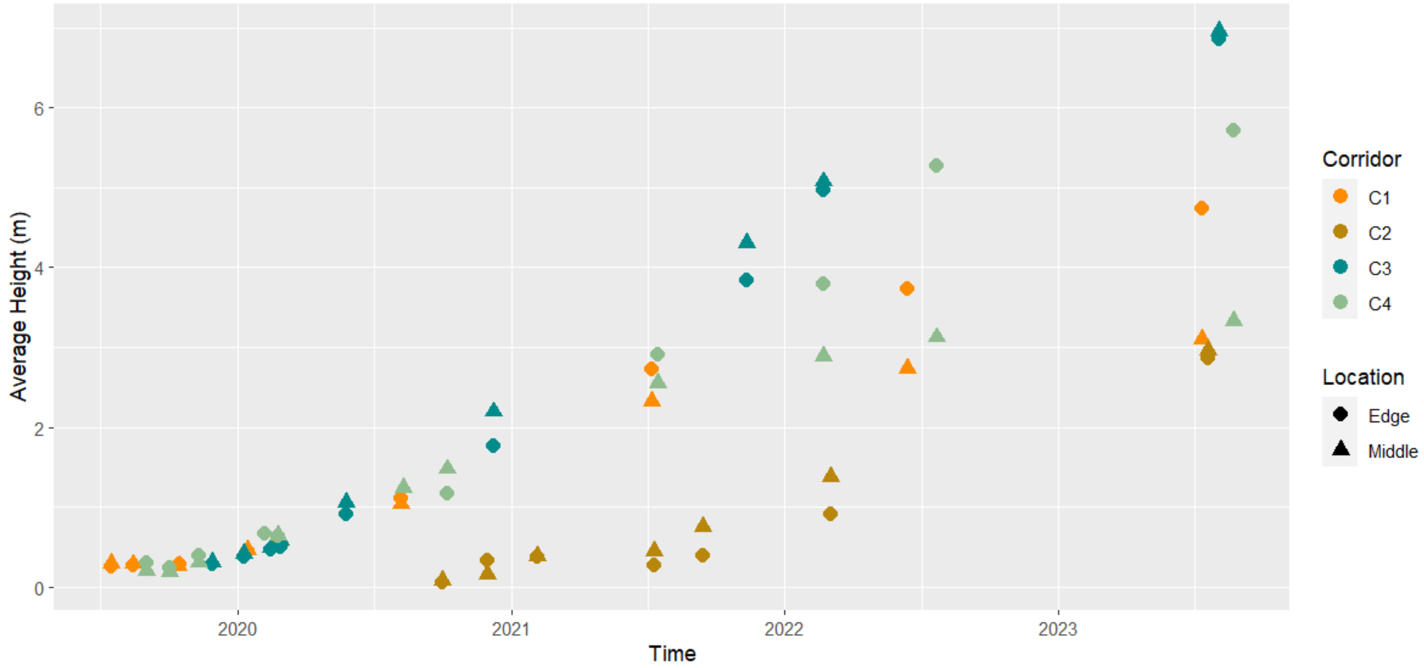

Figure 11: Average height of Acacia *in Corridor's 1 to 4, and how they differ on the edge or in the middle of the corridor.*

3.5.2 Native Seedling Survival and Growth

From the data collected quarterly, the average height of alive native seedlings in C1 to C4 was 25.92cm in April 2024. The height of alive native seedlings has changed throughout the last technical year (Figure 12); C2 had the highest growth rate of alive native seedlings (1.13cm/month), while C3 had the lowest (-1.09cm/month) (Table 2).

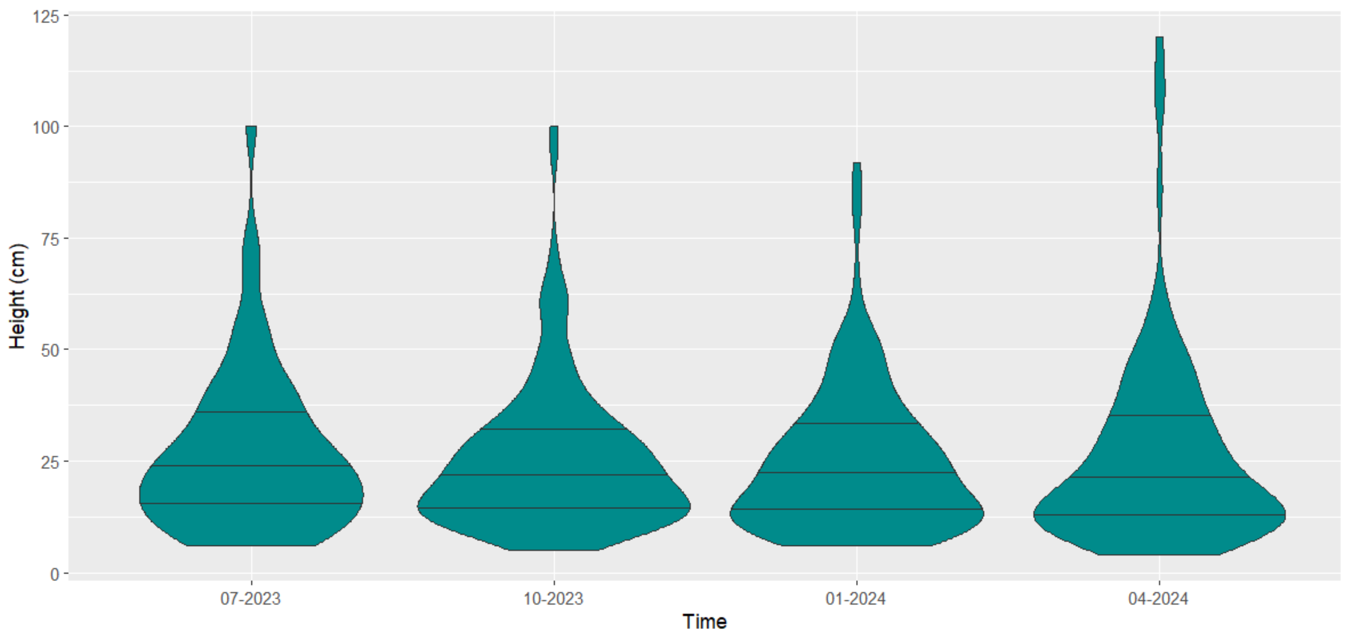

Figure 12: Graph of the heights of alive native plants in the forest corridors and how these have changed in the last technical year.[6] The width of the shapes corresponds to the frequency of plants with that height, with wider parts indicating more plants at that height. The lines across the shapes represent the median and upper and lower quartiles.

Table 2: Average height and growth rate of alive native seedlings in Corridor's 1 to 4 during the last technical year.

Corridor	Average Height (cm)				Average Growth (cm/month)
	July 2023	October 2023	January 2024	April 2024	
C1	17.64	21.07	16.16	19.78	0.24
C2	18.42	27.94	30.59	28.55	1.13
C3	39.86	33.29	30.18	30.02	-1.09
C4	32.00	18.59	21.88	37.00	0.56

The number of alive native seedlings planted before July 2023 decreases over time in the data collected monthly (Figure 13). In C4, 55% of native seedlings planted before July 2023 were alive during the last technical year, the lowest in any of the corridors. C1 had the highest proportion of alive native seedlings during the last technical year (81%). For the native seedlings planted in February 2024, there has been 100% survival in C1 and C2, 92% of the seedlings have survived in C3, and 87% have survived in C4.

[6] Data points included in this analysis collected before October 2023 were selected as they were able to be backtracked from the alive native seedlings labelled in October 2023. This included seedlings that had the same code and species as those identified in October 2023.

Figure 13: The number of alive native seedlings found in the Ala Programme's Forest corridors. Planting period 1 refers to all native seedlings planted before July 2023, and planting period 2 refers to all native seedlings planted in February 2024. Native seedlings were planted in C5 for the first time in February 2024 however, monitoring did not start until April 2024.

4 Discussion

4.1 Lemurs and other Mammals

Camera traps are able to identify arboreal primates in the canopy, such as *Prolemur simus* (Olson et al., 2012), and study detailed behaviour of large primates (Whitworth et al., 2019). Footage of one solitary *C. thomasi* captured in November 2022 in C3 proved the concept that the camera traps can successfully record lemurs in the corridors. In addition, arboreal camera trap studies have successfully captured images of mouse lemurs (*Microcebus jollyae*) (Chen, 2020). As such, if *M. tanosi* were to move within the detection range of the cameras, it is expected that they would be recorded in the corridors. Arboreal cameras produce significantly higher frequencies of non-target species trigger events, due to leaf movement (Gregory, Carrasco, Deichmann, Kolowski, & Alonso, 2014). Despite a large number of non-target species trigger events, it was confirmed that all mammal images captured were triggered by the movements of the animals themselves.

R. rattus was the most observed mammalian species in the forest corridors, with four records, all in C3 and all in the last technical year. *R. rattus* are habitat generalists and can be found in primary forests as well as in exotic tree plantations such as *Acacia* corridors (Ramanamanjato & Ganzhorn, 2001). *R. rattus* presence reduces as tree density and tree size increases (Ganzhorn, 2003), which suggests that as the corridors mature, fewer images of *R. rattus* would be captured. Studies in Madagascar have shown the presence of *R. rattus* does not exclude endemic small mammal species (e.g. *Microcebus murinus*, *Eliurus myoxinus)* from the habitat (Andriatsitohaina et al., 2020; Ganzhorn, 2003).

Research has found that as the DBH decreased there was an increase in the number of observations of some species of mouse lemur (Chen, 2020), and they have been found to use exotic *Acacia* forests or other degraded forest types, including regenerating forests, within as few as five years after planting (Andriamandimbiarisoa et al., 2015). Food availability, however, plays a large part of mouse lemur use of degraded forests (Fish, 2014). *M.*

tanosi are omnivorous (Donati et al., 2020a), and currently, the planted native seedlings and *Acacia* in the corridors do not provide adequate foraging habitat. As the native vegetation in the corridors matures and becomes a reliable food source, it will support additional invertebrates, as such *M. tanosi* are more likely to enter the corridors (Andriamandimbiarisoa et al., 2015).

A. meridonalis are a predominately folivorous species, feeding almost exclusively on leaves, with flowers being consumed occasionally (Norscia, Ramanamanjato & Ganzhorn, 2012). This species has shown a preference for habitats with a high density of large trees that facilitate their movement and provide a plentiful food supply (Adrianasolo et al., 2006). While the size and density of *Acacia* trees within the corridors are within the range that a species of Indriid (*Avahi laniger*) have been found to inhabit (Adrianasolo et al., 2006), it is unlikely that *A. meridonalis* will utilise the corridors for feeding until plentiful sources of native leaves are available.

E. collaris are mainly frugivorous but complement their diet with leaves and flowers. *While E. collaris* consume fruits of exotic tree species, the *Acacia* in the Ala Programme Corridors are not a fruiting species and subsequently will not draw the lemurs into the corridors in search of food (Donati et al., 2020d). Frugivorous species require larger home ranges to provide enough food resources for the population (Campera et al., 2014).

C. thomasi was synonymised with *Cheirogaleus medius,* as part of a recent revision of the genus *Cheirogaleus* (Lei et al., 2014; Ganzhorn et al., 2020). *C. medius* is an insect and fruit eater (Schwab & Ganzhorn, 2004), relying on habitats that provide tree holes for hibernation, sleep refugia during active months, and offspring safety. The corridors do not currently provide these ecological functions.

The corridors presently do not provide adequate food sources or sleeping sites for any of the four local lemur species. The corridors can, however, facilitate the movement of all four lemur species between the fragments through the provision of an intact canopy, which offers protection from aerial predators, and through trees of appropriate size, which facilitate various methods of transport. Thus, expanding home ranges through the Ala Programme, populations are presented with greater opportunities (Bertoncini et al., 2017). It is expected that rates of encounter, via camera trap imagery or opportunistic sightings, are likely to increase over time as habitat quality improves (Andriamandimbiarisoa et al., 2015).

4.2 Birds

Of the three observed species of bird, the Madagascar long-eared owl (*A. madagascariensis*) is the only species that is reliant on forest cover (Ellis, 2003). C3 has the most intact canopy of all the corridors and, as such, the presence of the long-eared owl here indicates that the forest structure is developed enough to provide temporary refuge for the species. The diet of *A. madagascariensis* in southeast Madagascar is dominated by *R. rattus* (Goodman, Langrand & Raxworthy, 1993). The presence of both these species in C3 suggests predator-prey interactions are occurring. Guinea fowl (*N. meleagris*) and Souimanga sunbirds (*C. sovimanga*) can be found in both forest and open land (Niekerk, 2002; Ellis, 2003). As all three bird observations occurred during the last technical year, it suggests that there is more activity in the corridors as they develop, this could be expected to increase over time.

4.3 Herpetofauna

Herpetofauna VES surveys are continuing in C1 to C4 to monitor how herpetofauna species richness and abundance change over time. Following trends in species accumulation to date, it is anticipated that the richness of forest-associated herpetofauna species will increase as the corridors mature. Five species were found in all corridors monitored: *F. lateralis*, *F. verrucosus*, *H. boettgeri, T. elegans*, and *T. gravenhorstii*, with a total of 15 species observed.

The skinks (*T. elegans* and *T. gravenhorstii*) and the snakes (*D. bernieri, M. meridionalis,* and *M. mahfalensis*) are all ground-dwelling species that can be found in both arid and humid habitats (Glaw & Vences, 2007; Raxworthy, 2011a; Raxworthy, 2011b; Vences, 2011). Two of the species of chameleon that were observed in the corridors (*F. lateralis* and *F. verrucosus*) favour arid land, however, they require herbaceous vegetation such as low bushes

(Jenkins et al., 2011b; Raxworthy, 2014). While species including Boettger's reed frog (*H. boettgeri*) and the Mascarene grass frog (*P. mascariensis*) require reliable water sources for breeding, these species are also generalists and occur in varying habitats (IUCN SSC Amphibian Specialist Group, 2016a). Interestingly, a species of chameleon (*C. nasutum*) was observed in C3, and a species of day gecko (*P. modesta*) in C2, C3, and C4. *C. nasutum* is a widely distributed species that is typically found in humid primary forest, secondary vegetation, and on forest edges, while *P. modesta* is widely distributed in arid parts of southeast Madagascar and typically observed on *Ravenala madagascariensis* (Glaw & Vences, 2007). The broad ecological habitat preferences of all these species explain their occupation of the dry and open current corridor habitat. As expected, species that are strictly native forest associated are not yet occupying the corridors. Observations of strongly arboreal species such as *C. nasutum, F. lateralis, F. verrucosus, I. oursi*, and *P. modesta* indicate the success of the ecological functioning of the planted trees.

The lowest species richness observed in the corridors was in C1. The *Acacia* trees in C1 have sparser foliar coverage than those in the other corridors, and there is more bare ground in C1, which may be limiting suitable habitat for herpetofauna within the corridor. In particular, the lack of leaf litter in the corridor could mean that there is no habitat for leaf litter dwelling species, such as *G. leucocephalus* (IUCN SSC Amphibian Specialist Group, 2016c), which were seen in large numbers in the forest remnants, but to date have not been seen in the forest corridors (SEED Madagascar, unpublished data).

Geckos were captured on camera trap footage during non-target trigger events caused by *Acacia* leaves moving in the wind. Of the geckos captured 75% were *P. modesta,* an arboricolous species found in drier climates (Raxworthy & Nussbaum, 1994). This species is less commonly found in established forests and is commonly found in artificial environments such as inside houses (Raxworthy, 2011c). Other species of *Phelsuma*, such as *P. parva*, are common in the surrounding forest fragments (SEED Madagascar, unpublished data), and are associated with established forest (Randrianantoandro, Glaw & Rakotondrazafy, 2011). As the Ala Programme's Forest corridors develop, it would be expected that *P. modesta* encounters decrease while *P. parva* encounters increase.

P. modesta were also seen sheltering behind the camera traps during routine checks. Artificial cover objects have been found to be attractive shelters for arboreal geckos (Bell, 2009). The *Acacia* in the corridors do not have many knot holes or much flaking bark to provide cover for arboreal reptile species, so the presence of the camera traps provides short-term protective shelter from both predators and the elements.

4.4 Invertebrate Biodiversity

Invertebrate assemblages in C1 to C4 are increasingly diverse and abundant. The orders encountered most frequently within the corridors were Orthoptera, Arachnida, and Hymenoptera. Orthoptera are the most encountered order in the corridors and are mainly found in open matrix ecosystems (INRAE – ephytia, 2022); this suggests that while the corridors are developing, they are still more similar to open matrix environments, such as grassland, than to closed matrix environments, such as forests. As the corridors continue to grow, more canopy cover and organic matter will result in the invertebrate communities observed in the corridors more closely resembling those observed in the forest remnants.

Orthoptera are large making them easy to detect and record. They are also solitary as they spatially outcompete conspecifics (INRAE – ephytia, 2022). As a result, their encounter rates are high, but the total abundance is low. In comparison, Hymenoptera are smaller and more difficult to find and catch, although they are often made up of large colonies of individuals (Robinson, 2005). Therefore, if one is found, it is often recorded alongside several other individuals.

Invertebrates are sensitive to environmental conditions, making them useful bioindicators to assess restoration efforts (Osborne, 2022; Orabi, 2012). Continued invertebrate surveying in the corridors and forest remnants will allow monitoring of changing invertebrate assemblages and species composition in the corridors as they mature. Invertebrate surveys contribute to the overall biodiversity monitoring of the Ala Programme as well as SCRP's wider understanding of local invertebrate biodiversity.

4.5 Floral Biodiversity

The *Acacia* in C1 to C4 have a mean height of over 2 metres. These *Acacia* can provide shade for slower-growing and shade-dependent native tree species, fix nitrogen into a nutrient-deficient substrate (Koutika & Richardson, 2019), and facilitate the reconnection of a range of species in fragmented habitat (Andriamandimbiarisoa et al., 2015, Chazdon et al., 2020, Gillies & Cassady St. Clair, 2008, Luckett et al., 2004, Schlaepfer, Sax & Olden, 2011, Singh et al., 2001). As such, it is expected that mature *Acacia* in the corridors will provide the structure, shade, and soil nutrients needed for native seedlings to grow. As the corridor *Acacia* are now deemed sufficient to fit this purpose, future replants will not be conducted.

Despite there being positive seedling growth across most corridors, growth was slow. One contributing factor could be the dense *Acacia* root systems which, when growing amongst other species, may cause below-ground competition (Kadir et al., 1998) and impact native seedling growth. In April 2024, the average height of alive native seedlings was greatest in C4 and smallest in C1, although no pattern was detected by corridor. While the average height was small in each of the corridors in April 2024, there were individual plants that were substantially taller, perhaps due to certain species being faster growing. In C3, the average height of native seedlings decreased, this could be due to the higher canopy cover in C3 provided by *Acacia* reducing the availability of sunlight for native seedlings, and thus impacting their growth. It could also be attributed to the accumulation of sand and leaf litter in the corridor, raising the level of the soil against the plant, thus giving the impression of a decline in seedling height. Despite this, averaged across all corridors the native seedlings that survive are slowly increasing in height. This measure has a high survivorship bias, as it does not include any native seedlings that die when calculating the growth rate or average height of native seedlings in each of the corridors.

At least 70% of all native seedlings monitored monthly have survived the last technical year. The highest proportion of alive native seedlings was found in C1. It is unconfirmed whether this is related to C1 having less dense *Acacia* trees. With a less dense canopy, the native seedlings may have increased sunlight hours, thus increasing their survival.

5 Conclusion

Since the inception of the Ala Programme in 2019, a variety of faunal species have been observed in the forest corridors, both as part of formal monitoring and opportunistic recording, with new species of herpetofauna, birds, and mammals observed in the corridors during the last technical year. Most herpetofauna and invertebrate species observed in the corridors are generalist species well suited to open matrix habitats. Since January 2022, however, four arboreal herpetofauna species have colonised the novel habitat. While there have been no observations of nocturnal lemurs within the corridors, there was an opportunistic sighting of four *E. collaris* crossing C1, and an additional opportunistic sighting of a *C. thomasi* eye-shine at the edge of R1 bordering C1. As native seedling size within the corridors increases, lemurs are expected to start utilising the corridors to facilitate their movement and feed.

In the coming years, the research produced by this Programme will provide a unique opportunity to increase understanding of littoral forest reforestation with the purpose of reconnecting fragmented forest. Madagascar has one of the highest rates of deforestation and environmental decline globally, yet with tangible evidence of successful reforestation projects, this trend can be mitigated.

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7 Annexes

Annex 1

Dates of the start of planting and data collection for *Acacia* and native seedlings in each of the Ala Programme's Forest corridors.

Corridor	Start of Planting: *Acacia*	Start of Data Collection: *Acacia*	Start of Planting: Natives	Start of Data Collection: Natives
C1	July 2019	16/07/2019	January 2020	08/02/2020
C2	July 2020	01/10/2020	January 2021	05/02/2021
C3	November 2019	28/11/2019	January 2020	14/02/2020
C4	August 2019	02/09/2019	January 2020	07/02/2020
C5	March 2022	03/09/2022	February 2024	11/04/2024[7]

Annex 2

Descriptions of each of the conditions assigned to the seedlings.

Condition	Description
1	Dead: Seedling has wilted, lost its leaves, and turned brown or is not visible
2	Poor: Severe signs of either damage, pest infestation, discolouration, fungi, or abnormal growth
3	Fair: Signs of either damage, pest/infestation, discolouration, fungi, or abnormal growth
4	Excellent: No signs of damage or pest/infestation, no discolouration or fungi growth and growing steadily

Annex 3

Table of all non-lemur faunal camera trap records.

Corridor	Species	Location in Corridor	Number of Observations
C1	Guinea fowl (*Numida meleagris*)	Middle	1
C2	Modest day gecko (*Phelsuma modesta*)	Edge	2
C3	Black rat (*Rattus rattus*)	Edge and Middle	4 (Edge: 3; Middle: 1)
	Modest day gecko (*Phelsuma modesta*)	Edge	1
	Bird (unknown)	Edge	1
	Madagascar long-eared owl (*Asio madagascariensis*)	Middle	1
	Gecko (unknown)[8]	Middle	1
C4	Indian Civet (*Viverricula indica*)	Edge	1
	Souimanga sunbird (*Cinnyris sovimanga*)	Middle	1

[7] The data collection for the native seedlings in C5 that started on 11/04/2024 was monthly data collection.

[8] Possibly *Phelsuma modesta* but it is unclear in this nocturnal photo.