Habitat requirements and assessment of a potential re-introduction site for the Mauritius Cuckoo-Shrike (*Coracina typica*) and Mauritius Paradise-flycatcher (*Terpsiphone desolata*)

Re-introductions are increasingly regarded as an important management technique to enable the re-establishment of populations of rare or threatened species and some sites in Mauritius are suitable for the re-introduction of Mauritius endemic species. Before a re-introduction is carried out a feasibility study is strongly recommended to ensure that the site is suitable for the species. The IUCN has developed guidelines based on best conservation practice for re-introduction methodology (IUCN 2013; Sutherland *et al*. 2010). The Mauritian Wildlife Foundation has contributed to this development of these guidelines based on its reintroduction experience. These guidelines are increasingly being adopted worldwide and increasingly being a requirement of funders and the scientific community to support reintroductions. The parameters that were investigated in this study are included in the reintroductions guidelines.

Habitat destruction and predation by introduced mammalian species, following the arrival of humans, are responsible for the decline of the threatened native passerines and for the extinction of at least 9 endemic bird species. By 1993, native vegetation on Mauritius had been reduced by 95% to 92.8 km^2. Much of the native vegetation has been replaced by invasive exotic species. Most of the remaining forest is wet evergreen and scrub forest; dry forest is rare and palm savannah has been wiped-out on the mainland. Native vegetation is highly fragmented and most of it is concentrated in the south-west of Mauritius. At present, most of the species are restricted to the remnant native forest of the south west of the island, although previously their distribution was more widespread. For some bird species, habitat similar to the remnant native forest of the south west exists in different parts of the island, but the small population size of these birds and the isolation from its current distribution may be preventing them from re-colonising these sites; their reintroduction to these areas could be trialed. However, before any reintroduction is attempted, we need to know more about these species' habitat requirements as well as their diet and predators.

The Mauritius Cuckoo-shrike (*Coracina typica*) is an endemic forest bird. Its population has decreased from approximately 210 – 220 pairs to around 100 – 250 individuals between 1975 and 2014 (Safford 1994, MWF 2014). The range is however still restricted in the south-west part of the island within 36 km² of relatively intact native forest and exotic tree plantation (Safford 1994). The intensive use of organochlorine pesticides in 1950s and 1960s is thought to have caused the rapid decline of Mauritius Cuckoo-shrike in the Bambous Mountains but these contaminants are no longer used worldwide (Safford 1994). The Mauritius Paradise-flycatcher (*Terpsiphone bourbonnensis desolata*) is a small forest dwelling passerine endemic to Mauritius. In 2014 its population was estimated at 400-800 individuals; an increase from the estimate of 320 pairs in 1975 (Safford 1994, MWF 2014). The decline of the Mauritius Paradise-flycatcher has been attributed to habitat loss and predation by mammalian exotics (Safford 1994). At present the subspecies is restricted to the remnant native forest of the south west and an exotic plantation in the north east of the island, although previously its distribution was more widespread (Safford 1994). Habitat similar to the remnant native forest of the south west exists in the Bambous Mountain Range on the East coast, but the small population size of these species and the isolation from its current distribution may be preventing them from re-colonising these sites (Cunningham 2008, Razafimanahaka 2008). Thus, it has been suggested in the past that the Bambous Mountain Range (Ferney Valley) along the east coast of Mauritius may be suitable for the re-introduction of Mauritius Paradise-flycatcher and the Mauritius Cuckoo-Shrike (BirdLife International 2016). Re-introductions are increasingly regarded as an important management technique to enable the re-establishment of populations of rare or threatened species (Fischer and Lindenmayer 2000, Whittaker and Fernández-Palacios 2007). So before re-introducing these species there, we need to know more about these species habitat requirements as well as their diet.

A survey was conducted at Ferney Valley, east Mauritius, to assess the suitability of a re-introduction of the Mauritius Cuckoo-Shrike and the Mauritius Paradise Flycatcher. Ferney Valley encloses around 200 hectares of rain forest which is home to more than a 100 flora species. Ferney and the surrounding forests of Bambous mountain range is home to the Mauritius Kestrel (*Falco punctatus*), currently classified as Endangered. The Mauritius Cuckoo-Shrike and the Mauritius Paradise Flycatcher were known to be present on the east coast before 1930s. The survey aimed to determine if Ferney Valley shares habitat characteristics that are associated with the Mauritius Cuckoo-Shrike and the Mauritius Paradise Flycatcher in their

remnant range. This was done once in the dry season (November-December 2013) and once in the wet season (March-April 2014).

The data from both season surveys were collected and entered in a dataset and compared to the data collected in areas where the Mauritius Cuckoo-Shrike (Brise Fer and Machabée) and the Mauritius Paradise Flycatcher (Pigeon Wood, Chamarel and Combo) are present. The data was analysed for the two seasons and the feasibility study report produced. This report hereunder provides a comparison of the characteristics of the extant distribution of the focal birds and proposed reintroduction site, as well as our conclusions regarding the feasibility of reintroduction of the two bird species.

1. Habitat survey

The habitat suitability survey 'dry' season was carried out on 12th December 2013 and 'wet' season was carried out on 27th March 2014 using four teams of 4 staff. 32 random points were generated within the area to be restored in the Ferney Valley using QGIS. Each team was allocated 8 points to cover. At each of the generated random point the following was recorded within a 100 m² quadrat (10 x10 m) (Bibby et al. 2000):

- Elevation measured using a Garmin Etrex GPS;
- Habitat type: Managed or unmanaged
- Vegetation type: Exotic, mix or native
- Canopy cover: defined as the proportion of sky obscured by the vegetation when looked at vertically from the four corners of the square quadrat and at the generated point (Jennings *et al*. 1999, Newton 2007). Four categories defined: 0 – 25 %, 25 – 50 %, 50 – 75 % and over 75 % canopy cover
- Canopy height estimated visually at the same five points;
- Spacing of trees; this was recorded as Low (less than 10 trees in 100 m²), Medium (between 10 and 20 trees in 100 m²) and High (more than 20 trees in 100 m²)
- Measure of secondary and tertiary branching, this was recorded as High (more than 10 branches), Medium (between 5 and 10 branches) and Low (less than 5 branches)
- Each tree of diameter at breast height (dbh) over 5 cm within the quadrat was counted, the species identified and height estimated

- If present, the number of Strawberry Guava *Psidium cattleianum* trees over 2 m height within the quadrat was counted and the density calculated as the number of guava per m². This plant was chosen as it is the most common invasive plant in these areas.
- Understorey density estimated in four categories defined: 0 – 25 %, 25 – 50 %, 50 – 75 % and over 75 % at two height categories, 0 – 2 m and 2 – 4 m.
- Ground cover: estimated using a 1 m² quadrat divided into 25 0.2 x 0.2 m squares used to estimate cover

For comparison, the same information about the habitat characteristics where the birds (Mauritius Cuckoo-shrike, Mauritius Paradise Flycatcher) are still surviving was recorded at 32 random points.

A multivariate analysis was run, data were analysed by fitting generalised linear models (GLMs), using the software package R.3.1.3 (R Development Core Team 2013). For the analysis of the different parameters, GLMs with bird species presence (Mauritius Cuckoo-shrike, Mauritius Paradise Flycatcher (current distribution) vs. Ferney Valley (absent)) and season (Wet, Dry) as treatment factors and survey point as a blocking factor were fitted to analyse variation in the response variables of the different habitat variables recorded. A blocking factor is a factor that has some effect on the response, but is of no interest to the experimenter; however, the variability it transmits to the response needs to be considered. Log-linear models with the relevant error distributions were used for the models. To account for statistical overdispersion, mean deviance changes were compared with *F*-tests (Crawley 2005).

Results

Habitat suitability

Altitude

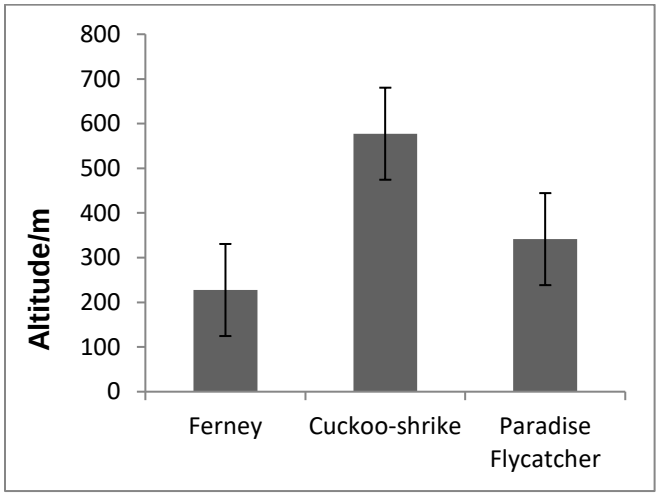


Figure 1: Average altitude at Ferney Valley and where Paradise Flycatcher and Cuckoo-shrike survives

It was found that Ferney Valley had significantly lower altitude ($F_{1,192}$= 650.8, P<0.0001) (Figure 1) compared to the altitude where both bird species were surviving. Furthermore, the Cuckoo-shrike was found at significantly higher altitude ($F_{1,191}$= 648.8, P<0.0001) than the Mauritius Paradise Flycatcher.

Habitat type (Managed/ Unmanaged)

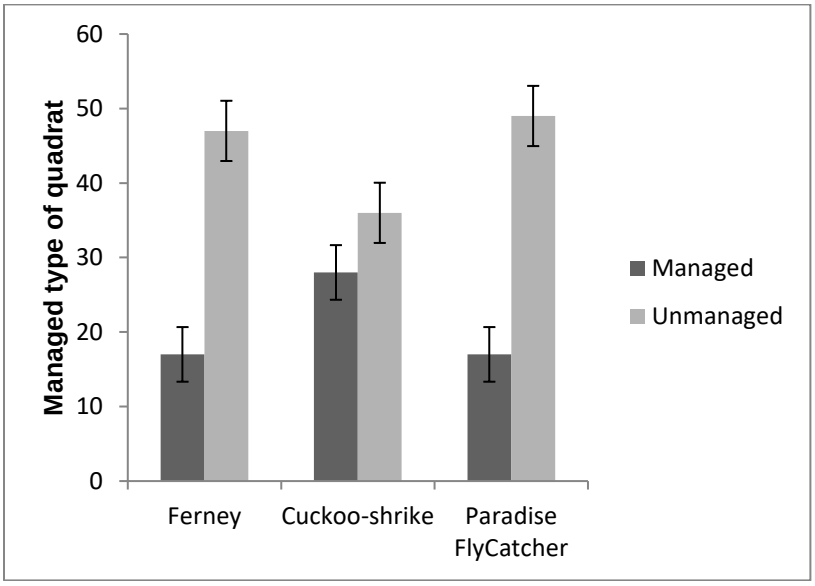


Figure 2: Number of quadrat type (Managed/unmanaged) at Ferney Valley and where the Mauritius Paradise Flycatcher and Mauritius Cuckoo-shrike survives

In terms of habitat, it was found that there was no significant difference in the number of quadrat that were managed and unmanaged ($F_{1,192}$= 1.3, P=0.253) (Figure 2) at Ferney Valley compared to where both bird species are surviving. However, the Mauritius Cuckoo-shrike was found significantly more in managed areas ($F_{1,191}$= 4.7, P=0.030) than the Mauritius Paradise Flycatcher. Flycatchers are also found in significantly more unmanaged areas than Mauritius Cuckoo-shrikes. Managed areas are defined as areas where exotic vegetation is removed to allow native and endemic vegetation to grow and where native and endemic plants may be replanted.

Vegetation type

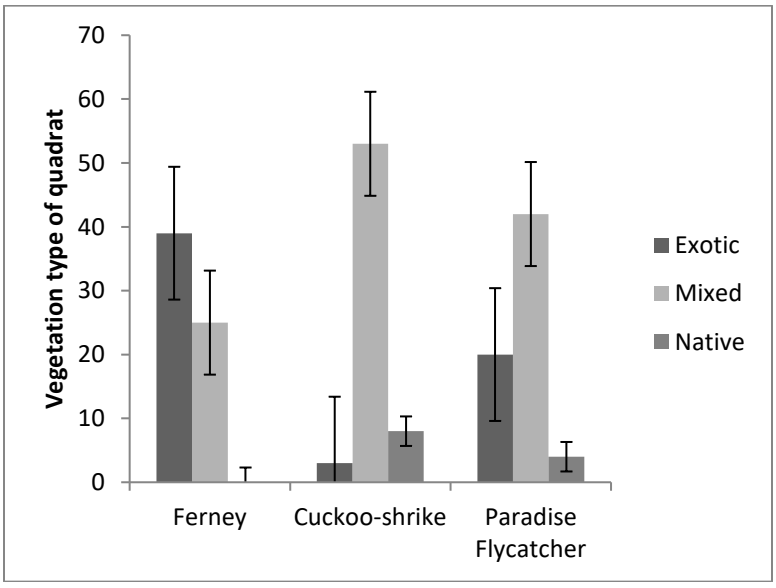


Figure 3: Number of quadrat vegetation type (Exotic, Mixed or Native) at Ferney Valley and where Mauritius Paradise Flycatcher and Mauritius Cuckoo-shrike survives

In terms of exotic and mixed vegetation, Ferney Valley had no difference ($F_{1,192}$= 0.03, P=0.855) compared to areas where both bird species are surviving. Furthermore, the Mauritius Cuckoo-shrike and the Mauritius Paradise Flycatcher were found to exhibit a similar preference for mixed vegetation type ($F_{1,191}$= 1.6, P=0.205). However, it was found that the Mauritius Paradise Flycatcher has a greater occurrence in exotic vegetation than does the Mauritius Cuckoo-shrike.

Canopy cover

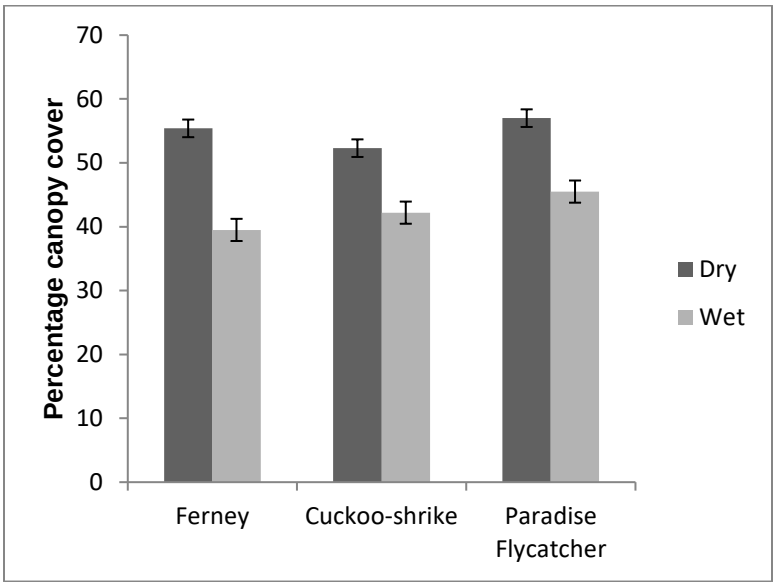


Figure 4: Percentage canopy cover at Ferney Valley and where Paradise Flycatcher and Mauritius Cuckoo-shrike survives

In terms of canopy cover, it was found that Ferney Valley had no significant difference ($F_{1,192}$= 2.6, P=0.109) compared to the areas where both bird species are surviving (Figure 4). We found that canopy cover significantly changed between the dry and wet season ($F_{1,190}$= 46.2, P<0.0001). However, the Mauritius Cuckoo-shrike used areas with less canopy cover significantly more than the Mauritius Paradise Flycatcher ($F_{1,191}$= 9.8, P=0.002) where these birds are surviving.

Canopy height

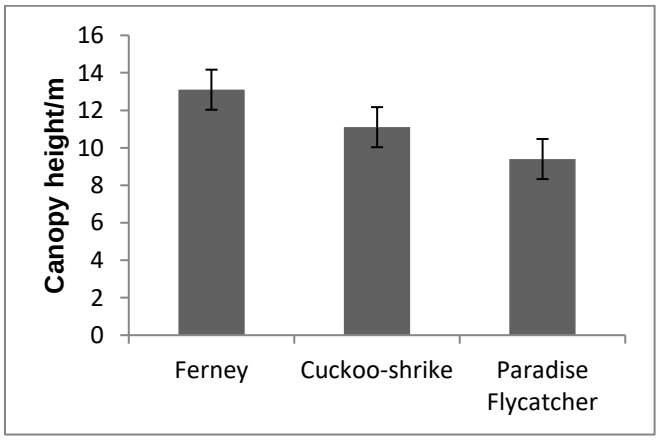


Figure 5: Average canopy height at Ferney Valley and where Mauritius Paradise Flycatcher and Mauritius Cuckoo-shrike survives

In terms of canopy height, it was found that Ferney Valley had significantly higher tree canopy ($F_{1,192}$= 30.9, P=0.0001) (Figure 5) compared to the areas where both bird species are surviving. However, the Mauritius Cuckoo-shrike used areas with high canopy significantly more than the Mauritius Paradise Flycatcher ($F_{1,191}$= 9.5, P=0.002), where these birds are surviving.

Spacing between tree trunks

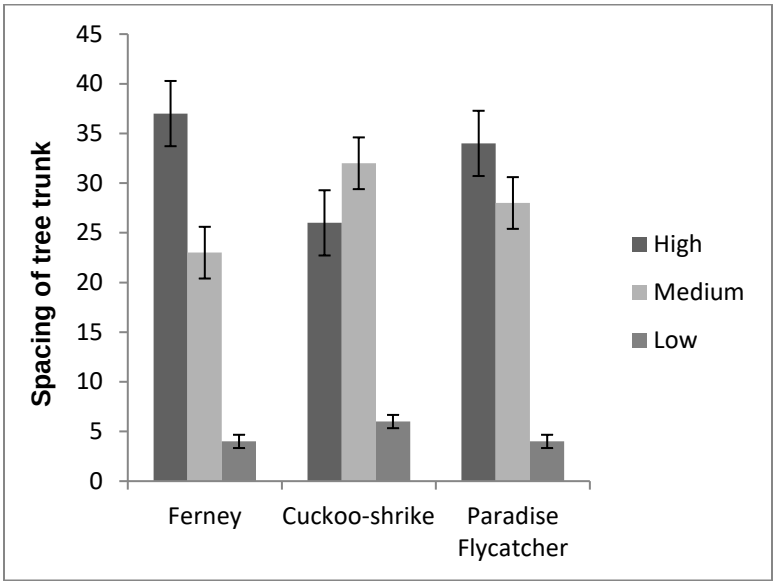


Figure 6: Average spacing type (High, Medium, Low) at Ferney Valley and where Paradise Flycatcher and Mauritius Cuckoo-shrike survives

In terms of spacing between tree trunks which correspond to the spacing density of the tree trunks, this was recorded as Low (less than 10 trees in 100 m²), Medium (between 10 and 20 trees in 100 m²) and High (more than 20 trees in 100 m²), it was found that Ferney Valley had no significant difference ($F_{1,192}$= 0.3, P=0.583) (Figure 6) compared to the areas where both focal bird species are found. Plant density at Ferney Valley was greater than at Brise Fer, Pigeon Wood, Chamarel and Combo. For the Mauritius Cuckoo-shrike and the Mauritius Paradise Flycatcher ($F_{1,191}$= 0.27, P=0.600) there was no significant difference in spacing between tree trunks (hence tree density) in the areas used by these birds.

Secondary branching

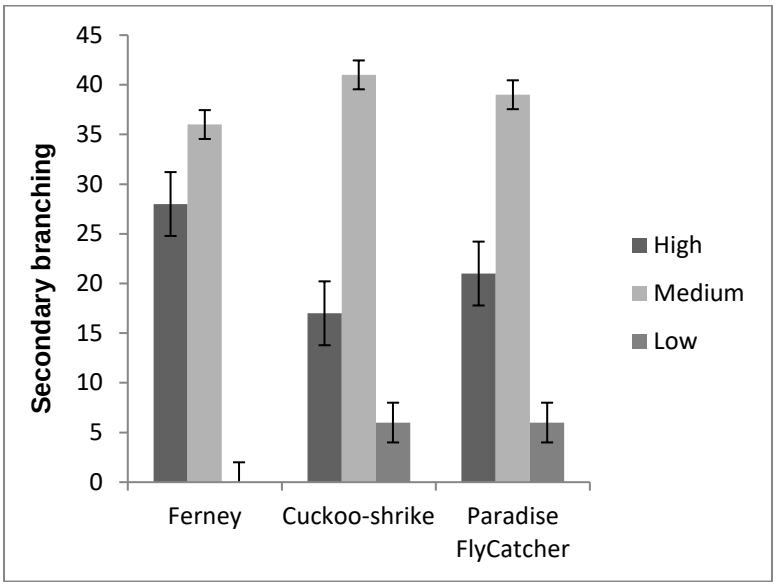


Figure 7: Average secondary branching type (High, Medium, Low) at Ferney Valley and where Mauritius Paradise Flycatcher and Mauritius Cuckoo-shrike survive.

In terms of secondary branching which correspond to the secondary branching density of the tree, this was recorded as High (more than 10 branches), Medium (between 5 and 10 branches) and Low (less than 5 branches); it was found that Ferney Valley had no significant difference ($F_{1,192}$= 1.0, P=0.306) (Figure 7) compared to the areas where both bird species were currently found. For the Mauritius Cuckoo-shrike and the Mauritius Paradise Flycatcher ($F_{1,191}$= 0.05, P=0.831) there is no significant difference in secondary branching in the places where these birds are found.

Tertiary branching

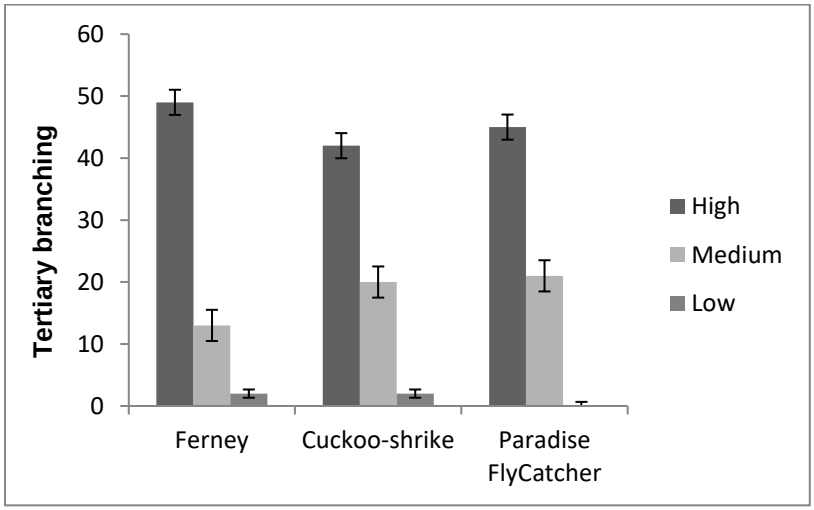


Figure 8: Average Tertiary branching type (High, Medium, Low) at Ferney Valley and where Mauritius Paradise Flycatcher and Mauritius Cuckoo-shrike survive.

In terms of tertiary branching which correspond to the tertiary branching density of the tree, this was recorded as High (more than 10 branches), Medium (between 5 and 10 branches) and Low (less than 5 branches); it was found that Ferney Valley had no significant difference ($F_{1,192}$= 1.0, P=0.748) (Figure 8) compared to the areas where both bird species are currently surviving. For the Mauritius Cuckoo-shrike and the Mauritius Paradise Flycatcher ($F_{1,191}$= 0.04, P=0.842) where they are surviving, there was no significant difference in use of plants with different types of tertiary branching.

Average number of tall trees

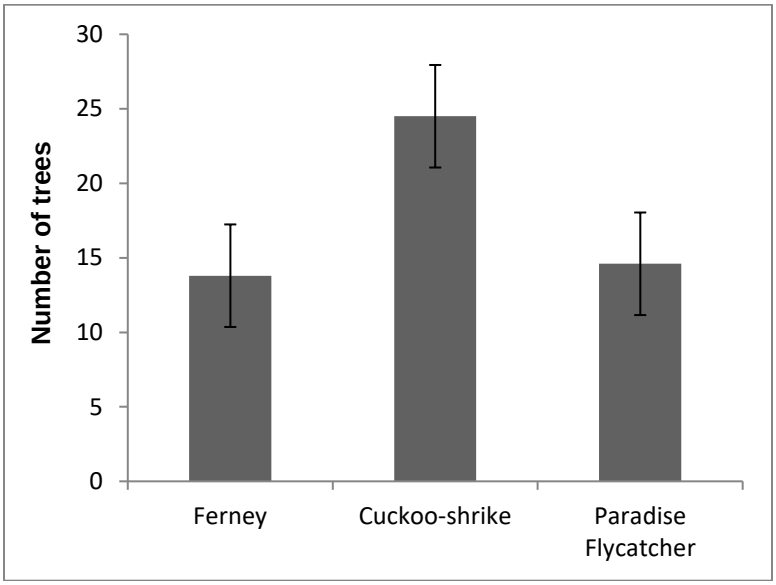


Figure 9: Average number of tall trees in 100 m² at Ferney Valley and where Mauritius Paradise Flycatcher and Mauritius Cuckoo-shrike survive.

In terms of number of tall trees (defined as trees with height > 5 m) found in the quadrat, it was found that Ferney Valley had significantly less tall trees in 100 m² quadrats ($F_{1,192}$= 81.5, P<0.0001) than where the Mauritius Cuckoo-shrike still survives, and there were no difference to where the Mauritius Paradise Flycatcher survives (Figure 9). Furthermore, the Mauritius Cuckoo-shrike used areas with high density of tall trees significantly more than the Mauritius Paradise Flycatcher ($F_{1,191}$= 163.6, P<0.0001).

Height of trees

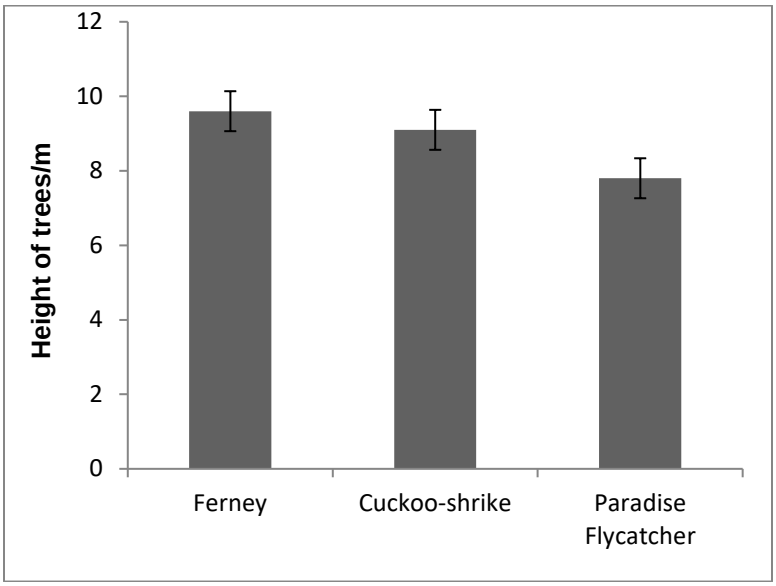


Figure 10: Average height of trees in 100 m² at Ferney Valley and where Paradise Flycatcher and Mauritius Cuckoo-shrike survives

In terms of height of trees, it was found that Ferney Valley had significantly taller trees ($F_{1,192}$= 6.9, P=0.008) (Figure 10) compared to the areas where both bird species are surviving. However, the Mauritius Cuckoo-shrike used areas with taller trees (trees > 5 m) more than the Mauritius Paradise Flycatcher ($F_{1,191}$= 6.1, P=0.013).

Density of Strawberry Guava trees

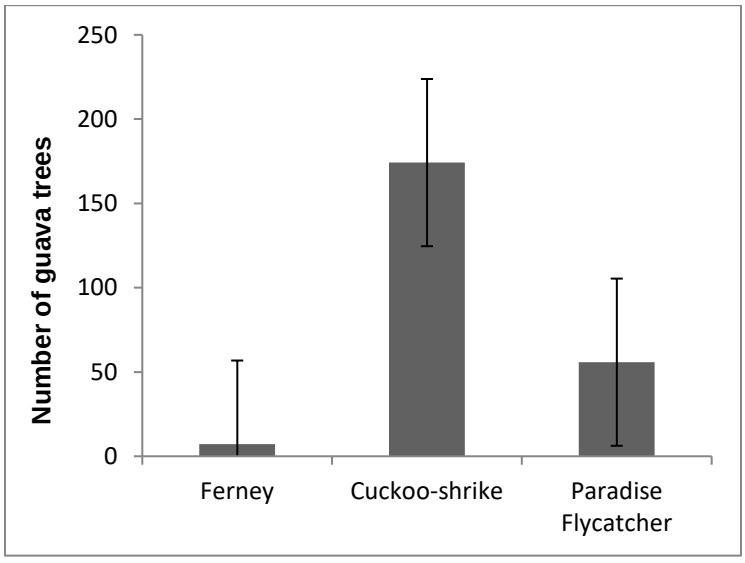


Figure 11: Average density of Strawberry guava in m² at Ferney Valley and where Mauritius Paradise Flycatcher and Mauritius Cuckoo-shrike survive.

In terms of density of guava trees, it was found that Ferney Valley had significantly less guava trees ($F_{1,192}$= 89.1, P<0.0001) compared to the areas where both bird species were surveyed (Figure 11). However, the Mauritius Cuckoo-shrike are present in areas with denser guava trees significantly more than the Mauritius Paradise Flycatcher ($F_{1,191}$= 41.8, P<0.0001).

Understorey foliage density between 0 and 2 m

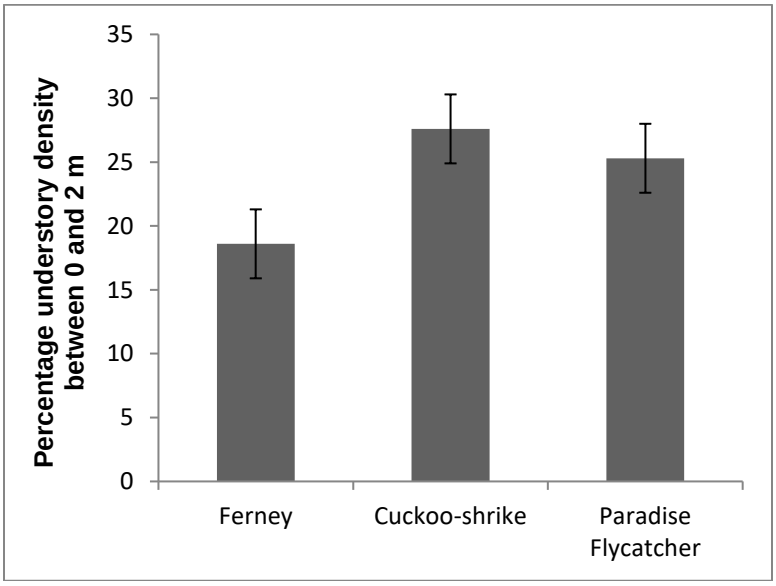


Figure 12: Percentage understorey foliage density between 0 and 2 m at Ferney Valley and where Mauritius Paradise Flycatcher and Mauritius Cuckoo-shrike survive.

In terms of the understorey foliage density (between 0 and 2 m), (we estimated the percentage foliage density in 2 m² at each corner of the quadrat), it was found that Ferney Valley had significantly less understory foliage ($F_{1,192}$= 15.4, P=0.0001) compared to the areas where both bird species are surviving ($F_{1,192}$= 15.4, P=0.0001) (Figure 12). However, there was no significant difference between the understorey foliage density in the areas used by the Mauritius Cuckoo-shrike and the Mauritius Paradise Flycatcher ($F_{1,191}$= 1.1, P=0.307).

Understorey foliage density between 2 and 4 m

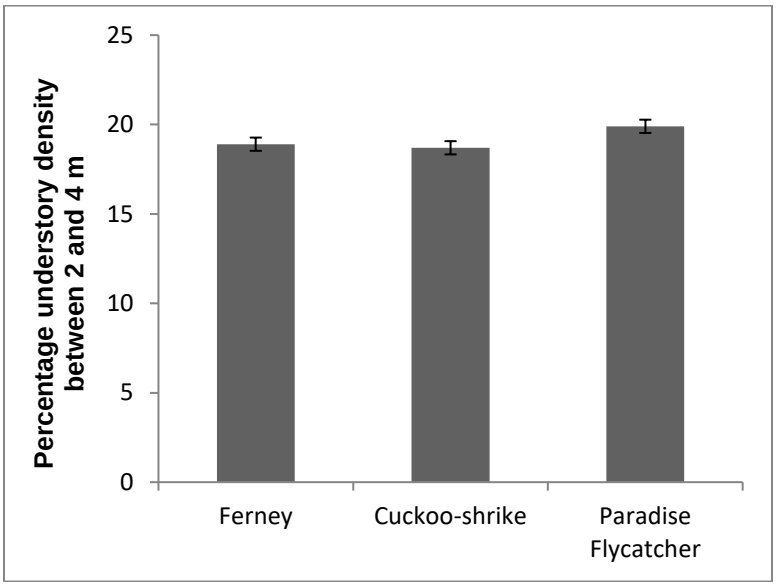


Figure 13: Percentage understorey foliage density between 0 and 4 m at Ferney Valley and where Mauritius Paradise Flycatcher and Mauritius Cuckoo-shrike.

In terms of foliage understorey density between 2 and 4 m (we estimated the percentage foliage density in 2 m² at each corner of the quadrat), it was found that Ferney Valley had no significant difference ($F_{1,192}$= 0.34, P=0.556) (Figure 13) compared to the areas where both bird species are surviving. There was no significant difference between the understorey foliage density ($F_{1,191}$= 2.23, P=0.135) in areas used by the Mauritius Cuckoo-shrike and the Mauritius Paradise Flycatcher.

Groundcover

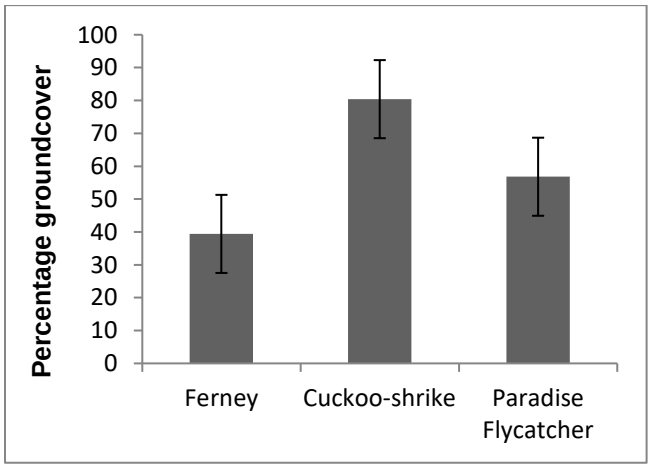


Figure 14: Percentage ground cover at Ferney Valley and where Mauritius Paradise Flycatcher and Mauritius Cuckoo-shrike survive.

In terms of ground cover, Ferney Valley had significantly less ground cover compared to the areas where both bird species were surveyed ($F_{1,192}$= 655.9, P<0.0001) (Figure 14). Furthermore, the Mauritius Cuckoo-shrike used significantly more areas with more ground cover than the Mauritius Paradise Flycatcher (However, both species are rarely seen on the ground) ($F_{1,191}$= 264.8, P<0.0001).

2. Invertebrate survey

The survey to investigate invertebrate diversity and relative densities was carried out in April 2014 using four teams for the “wet” season in November 2013 for the “dry” season. Invertebrate diversity and relative densities was estimated at the same points used for the habitat suitability using a combination of different methods.

Five water traps were arranged in a circle around the generated point, one in the middle and 4 at a fixed distance in each corner of the quadrat; a white pot of 12.5 cm diameter and 13 cm deep was suspended from a branch or attached on a trunk with an adhesive tape on a tree between 0.5 and 2 m height at each point (Ausden and Drake 2006; McGavin and Lewington 2001). Pots and traps were placed between 0900 h and 1530 h and collected between 1000 h and 1600 h the next day. The invertebrates collected were preserved in 70 % alcohol and later counted and identified in one of the field stations.

Tree bashing was also used for surveying insects. It is a method where a defined number of strikes with a stick are given to several branches over a receptacle, in this case a white bucket of 30 cm diameter by 40 cm depth, to collect the invertebrates falling from the vegetation. This method estimates invertebrates that are hiding in the vegetation (Ausden and Drake 2006; McGavin and Lewington 2001).

All the specimens collected by these three methods (water trap, aerial trap (pot) and tree bashing) were classified to Order and placed within size classes (0 – 5 mm, 5 – 10 mm, > 10 mm body length and body plus wing length for winged species).

Results

Invertebrate survey

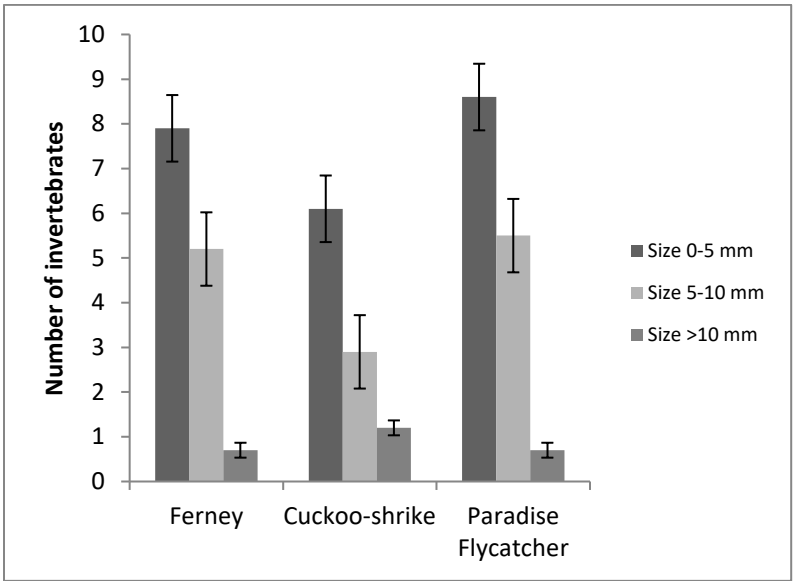
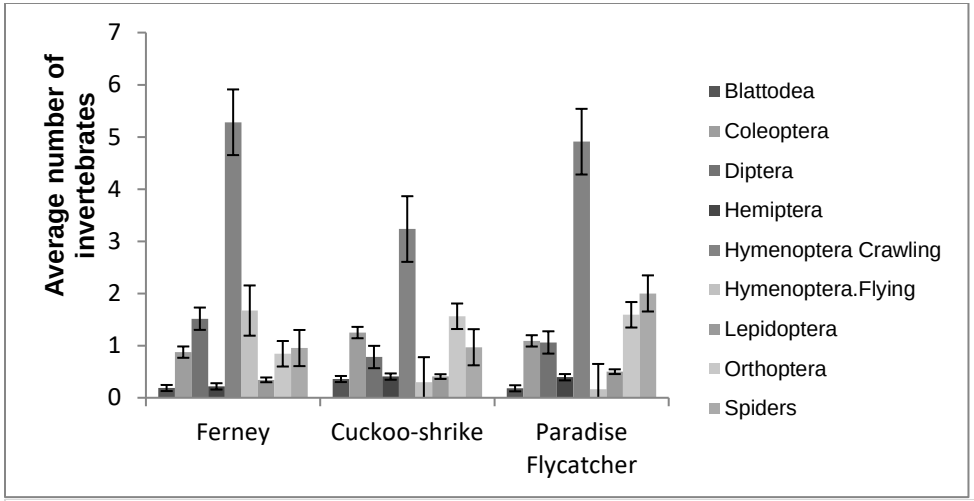


Figure 15: Count of invertebrates based on their size at Ferney Valley and where Mauritius Paradise Flycatcher and Mauritius Cuckoo-shrike survive.

In terms of number of insects between 0 and 5 mm, Ferney Valley had no significant difference ($F_{1,192}$= 2.13, P=0.144) (Figure 15) compared to the areas where both birds species were surveyed. In terms of number of insects between 5 and 10 mm, Ferney Valley had significantly more insects between 5 and 10 mm ($F_{1,192}$= 8.28, P=0.004) compared to the areas where both birds species were surveyed (Figure 15). In terms of number of insects over 10 mm, Ferney Valley had significantly more insects that were larger than 10 mm ($F_{1,192}$= 4.43, P=0.035) compared to where the birds were surviving (Figure 15). There was no significant difference in number of invertebrates for the three size categories between the dry and wet season in Ferney Valley and the areas where both bird species we are surviving ($F_{1,192}$= 1.96, P=0.161, $F_{1,192}$= 35.54, P= 0.656, $F_{1,192}$= 16.9, P=0.134).



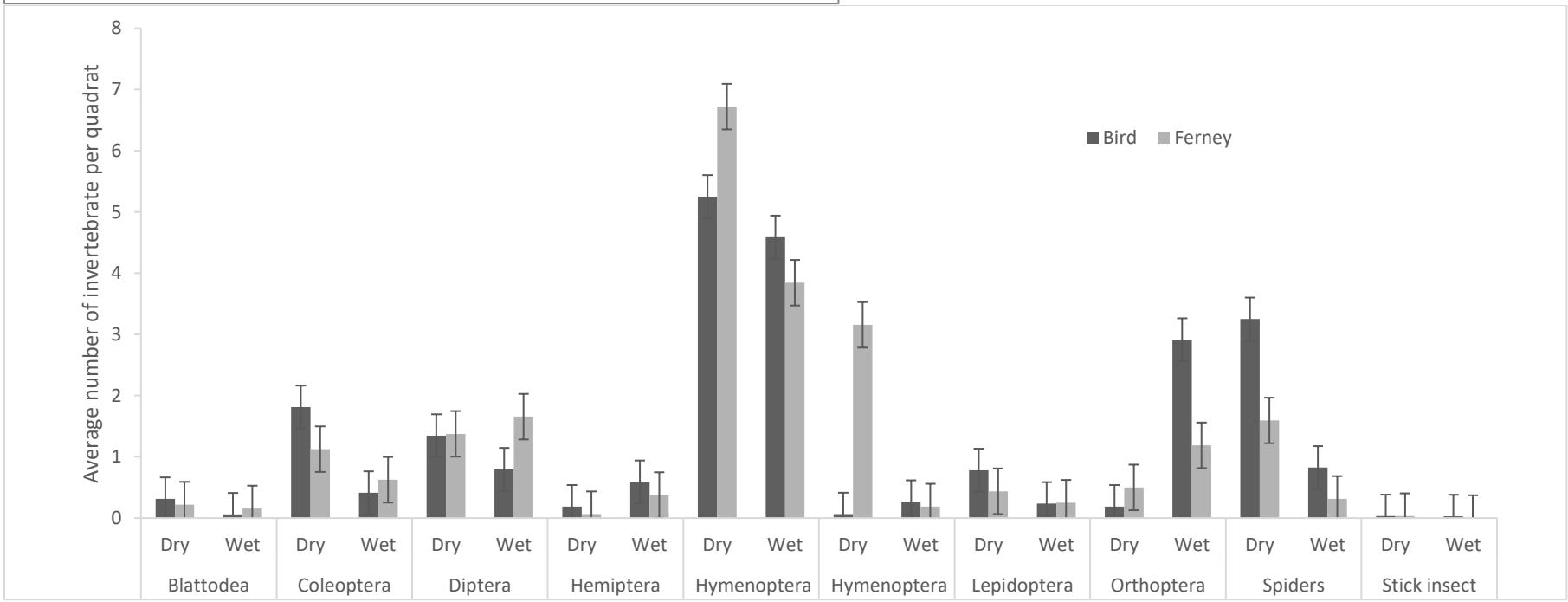


Figure 16: Average number of invertebrates based on group (upper graph) and per season (Lower graph) at Ferney Valley and where Mauritius Paradise Flycatcher and Mauritius Cuckoo-shrike survive.

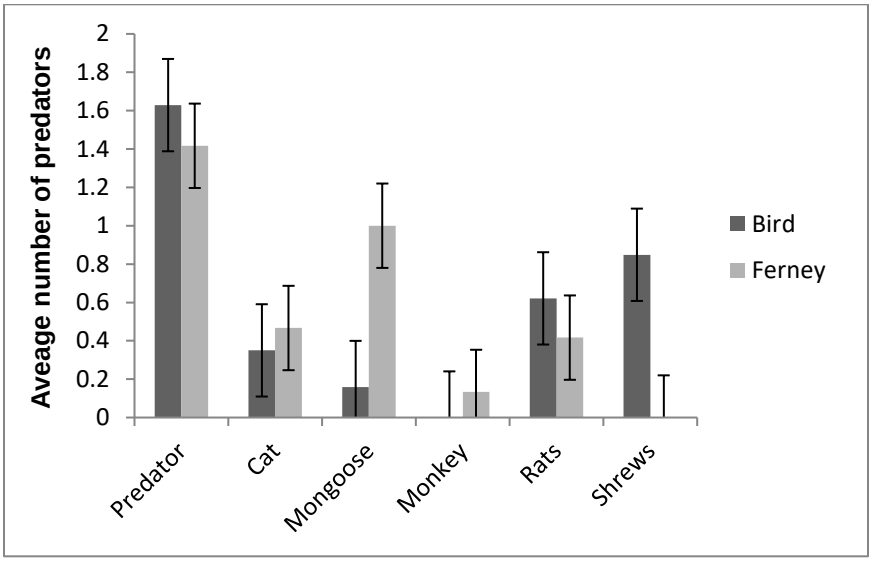
For the morpho-species, we found that for the blattodea (cockroaches), coleoptera (beetles) and lepidoptera (moths and butterflies), there was no significant difference between Ferney and the areas occupied by both species. It was found that Ferney Valley had significantly more diptera (Flies) ($F_{1,192}$= 655.9, P<0.0001), hemiptera (bugs) ($F_{1,192}$= 4.47, P=0.034), flying hymenoptera (wasps and bees) ($F_{1,192}$= 117.3, P<0.0001) and orthoptera (grasshoppers and crickets) ($F_{1,192}$= 117.3, P<0.0001) compared to the areas where both bird species were observed and there was no difference in the areas used by the Mauritius Cuckoo-shrike and the Mauritius Paradise Flycatcher. For the crawling hymenoptera (Ants), it was found that Ferney Valley had significantly more crawling hymenoptera ($F_{1,192}$= 13.4, P=0.0002) compared to the areas where both bird species were observed. Furthermore, the Mauritius Cuckoo-shrike used areas with less crawling hymenoptera ($F_{1,191}$= 22.5, P<0.0001) significantly more than the Mauritius Paradise Flycatcher. For the spiders, it was found that Ferney Valley had significantly less spiders ($F_{1,192}$= 10.0, P=0.002) compared to the areas where both bird species were observed. Furthermore, the Mauritius Cuckoo-shrike used areas with less spiders ($F_{1,191}$= 23.7, P<0.0001) significantly more than the Mauritius Paradise Flycatcher did. For both sites, it was found that more invertebrates were found in the wet compared to the dry season (Figure 16), however this was the opposite for the coleoptera, diptera, flying hymenoptera (wasps and bees) and spiders, that is more invertebrates were found in the dry compared to the wet season.

3. Predator survey

Predator diversity and relative abundance was carried out in the “wet” season on Tuesday 3rd May 2016 using five teams of 3 staff and the traps were checked and re-set on Wednesday 4th and Thursday 5th May, and on the 6th May the traps were removed and for the “dry” season from Wednesday 16th to Saturday 19th November 2016. Predator diversity and relative abundance was estimated using a combination of tracking tunnels and snap traps which should detect rodents, shrews and mongooses (Gillies and Williams 2009). Carbon-sooted baited square tiles and baited sand pits were used to detect larger predatory mammals like monkeys, mongooses, cats and dogs. Five parallel lines of tracking device separated by 50 m were set up in the areas; each line had 11 devices (3 tracking tunnels, 3 snap traps, 3 sooted tiles, 2 sand pits) separated by 10 m. The tunnels and tiles were checked every day for 3 days in the field (Gillies and Williams 2009). All marks were identified and counted to obtain relative abundance.

Results

Predator Survey



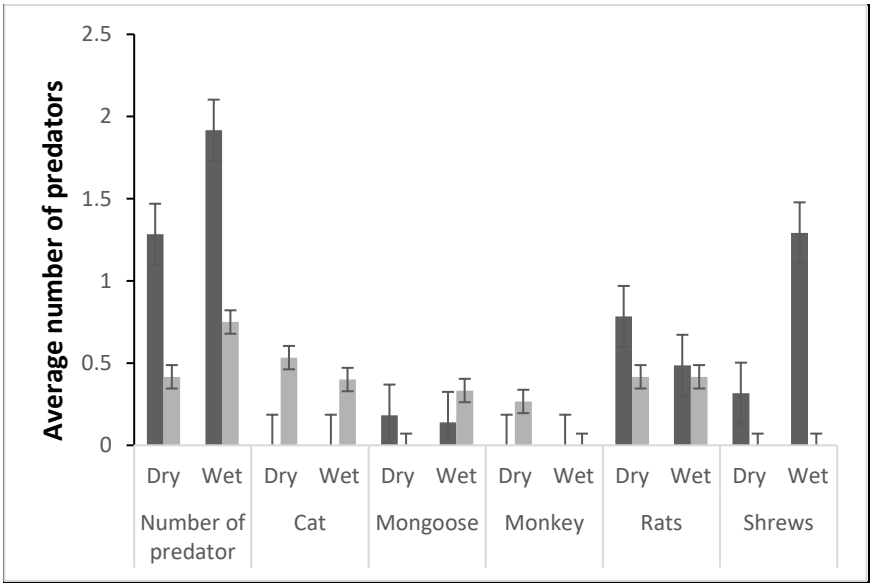


Figure 17: Average number of predator per 0.01 km² (upper graph) and per season per 0.01 km² (Lower graph) at Ferney Valley and where Mauritius Paradise Flycatcher and Mauritius Cuckoo-shrike survive.

For the total number of predators per 0.01 km² ($F_{1,153}$= 0.5, P=0.502) in Ferney Valley, Cats ($F_{1,153}$= 35.6, P= 0.457) and rats ($F_{1,153}$= 1.7, P=0.187), it was found that there was no significant difference between Ferney Valley compared to the areas where both bird species are surviving. However, there was a significant difference ($F_{1,154}$= 9.4, P=0.002) in the total number of predators and rats detected, more predators being detected in the wet compared to the dry season. However, for the mongoose we found that there was significantly more animals ($F_{1,153}$= 34.84, P<0.0001) in Ferney Valley compared to the areas where both bird species were observed and

this did not change with the season. Shrews are not predators of both bird species, and were not targeted in this survey, however their presence was recorded and presented in this report, but they have no known impacts on these two bird species. It was found that there was significantly less shrews ($F_{1,153}$= 35.6, P<0.0001) in Ferney Valley compared to the areas where both bird species were observed and this trend did change with the season ($F_{1,154}$= 42.5, P<0.0001). However, more shrews were detected in the wet season.

4. Gecko survey

The gecko survey was done seasonally, once in the dry season in November 2013 and once in the wet season in April 2014. A minimum of 32 random points was generated within the known range of the birds using QGIS. Gecko abundance at each generated point in the bird range was estimated using a point count survey method. A point close to the generated point was selected based on their visibility of the surrounding habitat. Once settled in the observer waited a minimum of 5 minutes before beginning the point count. During this time the observer remained immobile with their eyes closed. This break period allows any reptile that have been disturbed during the ascent to resume normal behaviour. Point counts was conducted over a 10 minute period. During each survey any reptile observed was recorded along, species. Binoculars were used to identify species.

Results
Gecko survey

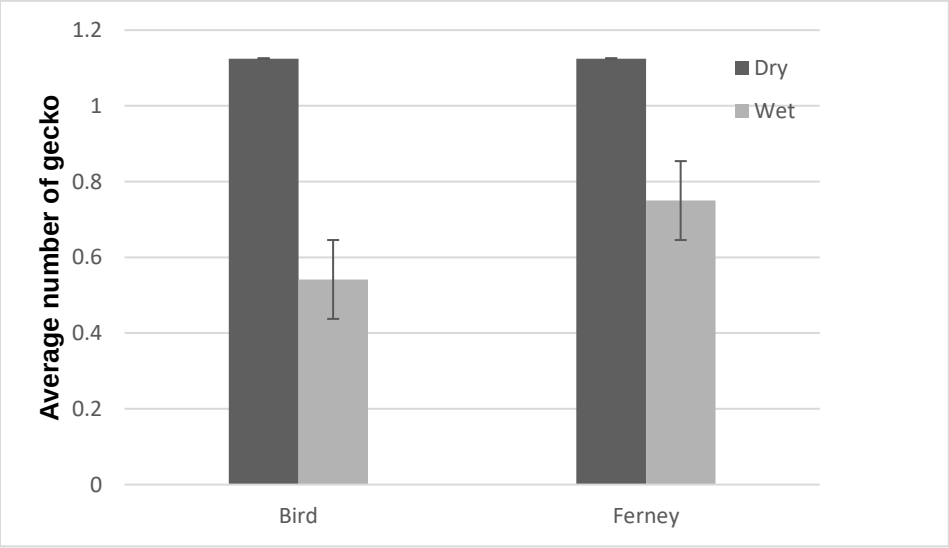


Figure 18: Average number of gecko per season in 100 m² at Ferney Valley and where Mauritius Paradise Flycatcher and Mauritius Cuckoo-shrike survive.

For the total number of geckos per 100 m², it was found that there was no significant difference ($F_{1,61}$= 0.14, P=0.699) (Figure 18) between Ferney Valley compared to the areas where Cuckoo-shrikes are surviving. However, there was a significant difference with the season ($F_{1,62}$= 5.34, P=0.021) in the total number of geckos at both side. More geckos were detected in the dry compared to the wet season.

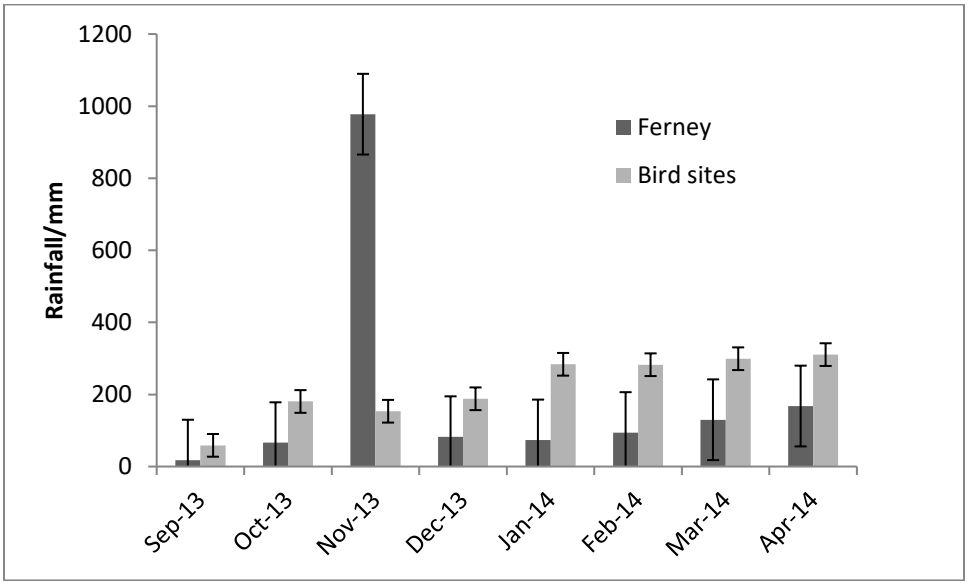
5. Climatic conditions

The climate at both sites was compared by either accessing available data or setting up representative weather stations using data loggers at Ferney and in the present distribution and repeat over time and across seasons.

Results

Climatic conditions

For the average rainfall, it was found that there was significantly more rainfall ($F_{1,13}$= 6.37, P=0.011) in Ferney Valley compared to the areas where both bird species are surviving and this also varied significantly with the months ($F_{1,14}$= 28.03, P<0.0001) (Figure 19). The rainfall for November might be a skew as for the other areas (bird sites) rainfall was higher than in Ferney Valley. For the average temperature, it was found that there was no significant difference between Ferney Valley and the areas where both bird species are surviving and this also did not vary significantly with the months (Figure 19).



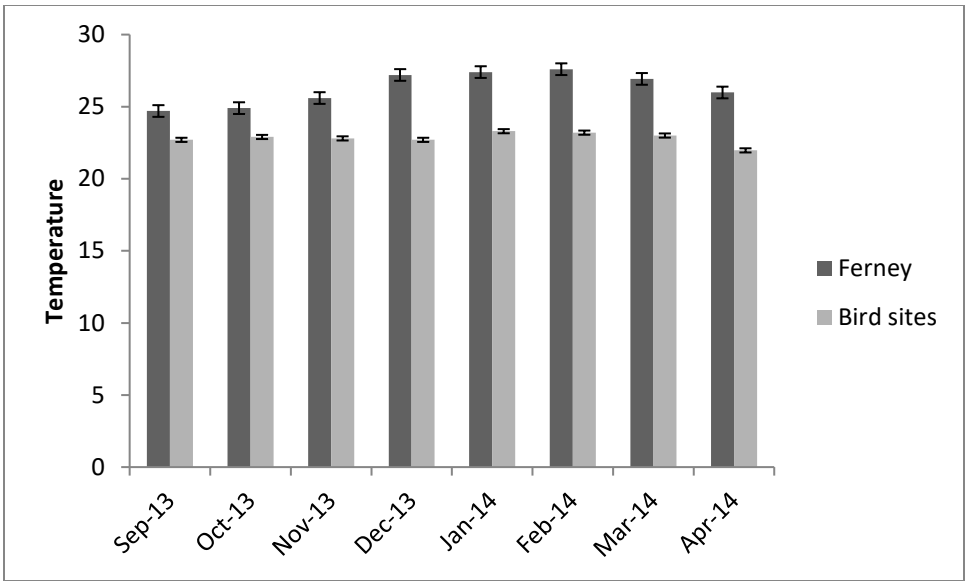


Figure 19: Rainfall in mm (upper graph) and temperature in °C (Lower graph) at Ferney Valley and where Mauritius Paradise Flycatcher and Mauritius Cuckoo-shrike survive.

Discussion

The study has shown that there are no significant differences between Ferney Valley and the forest hosting Mauritius Cuckoo-shrikes (Table 1) and Mauritius Paradise Flycatchers (Table 2) in terms of habitat type (managed or unmanaged), vegetation type (exotic, mixed or native), canopy cover, tree spacing, secondary and tertiary branching, and understorey foliage cover between 2 and 4 m. However, there are significant differences in habitat suitability between Ferney Valley and the current distribution of the Mauritius Cuckoo-shrike and Mauritius Paradise Flycatcher in terms of habitat - canopy height, height of trees, density of tall trees (> 5 m), understorey cover between 0 and 2 m and ground cover. None of these measured parameters changed between the wet and dry season, except for canopy cover and foliage density, in the areas where the Mauritius Cuckoo-shrike (Table 1) and Mauritius Paradise Flycatcher (Table 2) are still surviving, there was more canopy cover and foliage density in the dry compared to the wet season. But these parameters did not change with the season in Ferney Valley. To note that Brise Fer forest does not have Mauritius Paradise Flycatchers, whilst Chamarel and Combo have no Mauritius Cuckoo-shrikes.

Table 1: Summary of habitat and predator survey comparison for the areas occupied by Mauritius Cuckoo-shrike, and Ferney Valley (no Mauritius Cuckoo-shrike) and implications for re-introduction.

Parameter	Mauritius Cuckoo-shrike Habitat	Ferney Valley	Statistical significance	Season change	Effect for re-introduction
Altitude/m	577 ± 105	227 ± 35	$F_{1,192}$= 650.8, P<0.0001	No change	No effect
Number of managed quadrat	28 managed, 36 unmanaged	17 managed, 47 unmanaged	$F_{1,192}$= 1.3, P=0.253	No change	Positive as there is no change across site and season
Quadrat vegetation type	3 exotic, 53 mixed, 8 native	39 exotic, 25 mixed, 0 native	$F_{1,192}$= 0.03, P=0.855	No change	Positive as there is no change across site and season
Canopy cover %	47.2 ± 19.7	47.5 ± 22.8	$F_{1,192}$= 0.93, P=0.109	change	Positive as there is no change across site and but across season
Canopy height m	9 ± 4	13.1± 6.7	$F_{1,192}$= 30.9, P<0.0001	No change	Positive as there is no change across site and season
Spacing between trees m	26 High, 32 Medium, 6 Low	37 High, 23 Medium, 4 Low	$F_{1,192}$= 0.3, P=0.583	No change	Positive as there is no change across site and season
Secondary branching %	17 High, 41 Medium, 6 Low	28 High, 36 Medium, 0 Low	$F_{1,192}$= 1.0, P=0.306	No change	Positive as there is no change across site and season
Tertiary branching %	42 High, 20 Medium, 2 Low	49 High, 13 Medium, 2 Low	$F_{1,192}$= 1.0, P=0.748	No change	Positive as there is no change across site and season
Number of tall trees/quadrat	24±9	14±9	$F_{1,192}$= 81.5, P<0.0001	No change	Negative as there is a difference across site
Height of trees m	9.1±2.5	9.6±3.7	$F_{1,192}$= 6.9, P=0.008	No change	Positive as there is positive change across site and no change across season

Density of strawberry guava/m²	1.7±2.9	0.06±0.1	$F_{1,192}$= 89.1, P<0.0001	No change	Positive as there is positive change across site and no change across season
Understory foliage density (between 0 and 2 m) %	27.7 ± 15.8	18.6 ± 9.1	$F_{1,192}$= 15.4, P=0.0001	No change	Negative as there is a difference across site
Understory foliage density (between 2 and 4 m) %	18.7 ± 13.3	18.9 ± 11.1	$F_{1,192}$= 0.34, P=0.556	No change	Positive as there is no change across site and season
Groundcover %	80.4 ± 16.9	39.4 ± 24.1	$F_{1,192}$= 655.9, P<0.0001	No Change	Negative as there is a difference across site
Insects between 0 and 5 mm per 5 m²	6.1 ± 6.8	7.9 ± 8.8	$F_{1,192}$= 2.13, P=0.144	No Change	Positive as there is no change across site and season
Insects between 5 and 10 mm per 5 m²	2.9 ± 2.8	5.2 ± 4.5	$F_{1,192}$= 8.28, P=0.004	No Change	Positive as there is positive change across site and no change across season
Insects bigger than 10 mm	1.2 ± 1.5	0.6 ± 1.0	$F_{1,192}$= 4.43, P=0.035	No Change	Positive as there is positive change across site and no change across season
Number of Blattodea per 5 m²	0.4 ± 0.7	0.1 ± 0.5	$F_{1,192}$= 23. 74, P=0.145	Changes	Positive as there is no change across site
Number of Coleopera per 5 m²	1.3 ± 1.4	0.9 ± 1.1	$F_{1,192}$= 10.53, P=0.236	Changes	Positive as there is no change across site
Number of Diptera per 5 m²	0.8 ± 1.1	1.5 ± 1.6	$F_{1,192}$= 655.9, P<0.0001	Changes	Positive as there is positive change across site
Number of Hemiptera per 5 m²	0.4 ± 1.0	0.2 ± 0.7	$F_{1,192}$= 4.47, P=0.034	Changes	No effect

Number of crawling Hymenoptera per 5 m²	3.23 ± 4.3	5.3 ± 7.4	$F_{1,192}$= 13.4, P<0.0001	Changes	Positive as there is positive change across site
Number of flying Hymenoptera per 5 m²	0.3 ± 0.7	1.7 ± 5.7	P<0.0001	Changes	Positive as there is positive change across site
Number of Lepidoptera per 5 m²	0.4 ± 0.9	0.3 ± 0.6	$F_{1,192}$= 0.93, P=0.335	Changes	Positive as there is no change across site
Number of Orthoptera per 5 m²	1.6 ± 3.0	0.8 ± 1.7	$F_{1,192}$= 1.96, P=0.161	Changes	Positive as there is no change across site
Number of Spiders per 5 m²	0.9 ± 1.1	0.9 ± 1.1	$F_{1,192}$= 10.68, P=0.002	Changes	Negative as there is a difference across site and season
Number of Stick insects per 5 m²	0.1 ± 0.1	0.1 ± 0.1	$F_{1,192}$= 10.0, P=0.332	No change	Positive as there is no change across site
Number of predators per 0.01 km²	1.6 ± 1.8	1.4 ± 0.9	$F_{1,153}$= 0.5, P=0.502	Changes	Positive as there is no change across site
Number of cats per 0.01 km²	0.1 ± 0.1	0.2 ± 06	$F_{1,153}$= 35.6, P= 0.457	No change	Positive as there is no change across site
Number of mongooses per 0.01 km²	0.2 ± 0.5	1.0 ± 0.9	$F_{1,153}$= 34.84, P<0.0001	No change	Negative as there is a difference across site and season
Number of monkeys per 0.01 km²	0.1 ± 0.1	0.8 ± 0.3	$F_{1,159}$= 12,88, P=0.001	Changes	Negative as there is a difference across site and season
Number of rats per 0.01 km²	0.6 ± 1.1	0.4 ± 0.7	$F_{1,153}$= 1.7, P=0.187	Changes	Positive as there is no change across site
Presence of geckos	0.8 ± 1.6	0.9 ± 1.9	$F_{1,61}$= 0.14, P=0.699	Changes	Positive as there is no change across site
Rainfall	219.6 ± 88.9	201.3 ± 316.8	$F_{1,13}$= 6.37, P=0.011	Changes	Positive as there is

					positive change across site
Temperature	26.3 ± 1.1	22.8 ± 0.4	$F_{1,13}$= 1.7, P=0.187	Changes	Positive as there is no change across site

Table 2: Summary of habitat, invertebrate and predator survey comparison for the areas occupied by Mauritius Paradise Flycatcher and Ferney Valley (no flycatcher) and implications for re-introduction.

Parameter	Flycatcher Habitat	Ferney Valley	Statistical significance	Season change	Effect for re-introduction
Altitude/m	341 ± 34	227 ± 35	$F_{1,192}$= 650.8, P<0.0001	No change	No effect
Number of managed quadrat	17 managed, 47 unmanaged	17 managed, 47 unmanaged	$F_{1,192}$= 1.3, P=0.253	No change	Positive as there is no change across site and season
Quadrat vegetation type	20 exotic, 42 mixed, 4 native	39 exotic, 25 mixed, 0 native	$F_{1,192}$= 0.03, P=0.855	No change	Positive as there is no change across site and season
Canopy cover/ %	51 ± 18	47.5 ± 22.8	$F_{1,192}$= 0.93, P=0.109	change	Positive as there is no change across site and but across season
Canopy height/m	9 ± 3	13.1± 6.7	$F_{1,192}$= 30.9, P<0.0001	No change	Positive as there is no change across site and season
Spacing between trees m	34 High, 28 Medium, 4 Low	37 High, 23 Medium, 4 Low	$F_{1,192}$= 0.3, P=0.583	No change	Positive as there is no change across site and season
Secondary branching %	21 High, 39 Medium, 6 Low	28 High, 36 Medium, 0 Low	$F_{1,192}$= 1.0, P=0.306	No change	Positive as there is no change across site and season
Tertiary branching %	45 High, 21 Medium, 0 Low	49 High, 13 Medium, 2 Low	$F_{1,192}$= 1.0, P=0.748	No change	Positive as there is no change across site and season
Number of tall trees/quadrat	15±9	14±9	$F_{1,192}$= 81.5, P<0.0001	No change	Negative as there is a difference across site
Height of trees/m	7.8±1.9	9.6±3.7	$F_{1,192}$= 6.9, P=0.008	No change	Positive as there is positive change across site and no change across season

Density of strawberry guava/m²	0.6±0.9	0.06±0.1	$F_{1,192}$= 89.1, P<0.0001	No change	Positive as there is positive change across site and no change across season
Understory foliage density (between 0 and 2 m) %	25.3 ± 13.4	18.6 ± 9.1	$F_{1,192}$= 15.4, P=0.0001	No change	Negative as there is a difference across site
Understory foliage density (between 2 and 4 m) %	19.9 ± 13.9	18.9 ± 11.1	$F_{1,192}$= 0.34, P=0.556	No change	Positive as there is no change across site and season
Groundcover %	56.8 ± 26.6	39.4 ± 24.1	$F_{1,192}$= 655.9, P<0.0001	No Change	Negative as there is a difference across site
Insects between 0 and 5 mm per 5 m²	8.6 ± 6.5	7.9 ± 8.8	$F_{1,192}$= 2.13, P=0.144	No Change	Positive as there is no change across site and season
Insects between 5 and 10 mm per 5 m²	5.5 ± 6.5	5.2 ± 4.5	$F_{1,192}$= 8.28, P=0.004	No Change	Positive as there is positive change across site and no change across season
Insects bigger than 10 mm	0.7 ± 1.0	0.6 ± 1.0	$F_{1,192}$= 4.43, P=0.035	No Change	Positive as there is positive change across site and no change across season
Number of Blattodea per 5 m²	0.2 ± 0.9	0.1 ± 0.5	$F_{1,192}$= 23. 74, P=0.145	Changes	Positive as there is no change across site
Number of Coleopera per 5 m²	1.1 ± 1.5	0.9 ± 1.1	$F_{1,192}$= 10.53, P=0.236	Changes	Positive as there is no change across site
Number of Diptera per 5 m²	1.1 ± 1.4	1.5 ± 1.6	$F_{1,192}$= 655.9, P<0.0001	Changes	Positive as there is positive change across site
Number of Hemiptera per 5 m²	0.4 ± 0.7	0.2 ± 0.7	$F_{1,192}$= 4.47, P=0.034	Changes	No effect
Number of crawling Hymenoptera per 5 m²	4.9 ± 3.9	5.3 ± 7.4	$F_{1,192}$= 13.4, P<0.0001	Changes	Positive as there is positive change across site
Number of flying Hymenoptera per 5 m²	0.2 ± 0.5	1.7 ± 5.7	P<0.0001	Changes	Positive as there is positive change across site

Number of Lepidoptera per 5 m²	0.5 ± 0.8	0.3 ± 0.6	$F_{1,192}$= 0.93, P=0.335	Changes	Positive as there is no change across site
Number of Orthoptera per 5 m²	1.6 ± 4.0	0.8 ± 1.7	$F_{1,192}$= 1.96, P=0.161	Changes	Positive as there is no change across site
Number of Spiders per 5 m²	2.0 ± 2.9	0.9 ± 1.1	$F_{1,192}$= 10.68, P=0.002	Changes	Negative as there is a difference across site and season
Number of Stick insects per 5 m²	0.1 ± 0.1	0.1 ± 0.1	$F_{1,192}$= 10.0, P=0.332	No change	No effect
Number of predators per 0.01 km²	1.6 ± 1.8	1.4 ± 0.9	$F_{1,153}$= 0.5, P=0.502	Changes	Positive as there is no change across site
Number of cats per 0.01 km²	0.1 ± 0.1	0.2 ± 06	$F_{1,153}$= 35.6, P= 0.457	No change	Positive as there is no change across site
Number of mongooses per 0.01 km²	0.2 ± 0.5	1.0 ± 0.9	$F_{1,153}$= 34.84, P<0.0001	No change	Negative as there is a difference across site and season
Number of monkeys per 0.01 km²	0.1 ± 0.1	0.8 ± 0.3	$F_{1,159}$= 12,88, P=0.001	Changes	Negative as there is a difference across site and season
Number of rats per 0.01 km²	0.6 ± 1.1	0.4 ± 0.7	$F_{1,153}$= 1.7, P=0.187	Changes	Positive as there is no change across site
Rainfall	219.6 ± 88.9	201.3 ± 316.8	$F_{1,13}$= 6.37, P=0.011	Changes	Positive as there is positive change across site
Temperature	26.3 ± 1.1	22.8 ± 0.4	$F_{1,13}$= 1.7, P=0.187	Changes	Positive as there is no change across site

Ferney Valley has less native forest and tree diversity than the areas where the Mauritius Cuckoo-shrike and Mauritius Paradise Flycatcher are found. Native forests have taller trees, more understorey and ground cover. However, key factors for these birds, like tree density, canopy cover and height, secondary and tertiary branching and foliage density do not differ between Ferney Valley and the areas where the birds are surviving. Thus, the habitat at Ferney Valley is suitable for the reintroduction of the Mauritius Cuckoo-shrike and the Mauritius Paradise Flycatcher. Active restoration is taking place in Ferney Valley and this should result in the Ferney Valley having a good native forest similar to the one in the actual distribution of the Mauritius Cuckoo-shrike and the Mauritius Paradise Flycatcher.

Survey for invertebrate density and diversity has shown that Ferney Valley was not very different from sites where the Mauritius Cuckoo-shrike and the Mauritius Paradise Flycatcher are currently found. From our field observations, we know that Mauritius Paradise Flycatcher feed mostly on flying insects and the Mauritius Cuckoo-shrike for arboreal insects. There were no differences in density of the different size classes of invertebrates, for the dry and wet season in Ferney Valley and the areas where the species are surviving. In terms of the density of the different morpho-species, Ferney Valley was not significantly different to where the Mauritius Cuckoo-shrike and the Mauritius Paradise Flycatcher are found now. For all sites, it was found that more invertebrates were found in the wet compared to the dry season. As there is a higher density of blattodea, coleoptera, diptera, flying hymenoptera, lepidoptera, orthoptera and spiders, in Ferney Valley compared to where the birds are surviving now, this is positive as the birds should find enough invertebrates at Ferney Valley to feed on. If birds are re-introduced, this will greatly help them to settle in their new habitat and survive. However, since there are less spiders, that might be a problem, as Mauritius Cuckoo-shrike and the Mauritius Paradise Flycatcher feeds on spiders but most importantly use the cobwebs to build their nest, but we do not foresee this as a problem.

For the predator density and diversity, our study showed that Ferney Valley had fewer cats and rats than in the actual distribution of the native birds. However, Ferney had more mongooses than in the actual distribution of the native birds. This may be due to the presence of vast area of sugar cane fields around the valley. The number of rats are probably kept lower due to the high density of mongoose in the areas. This is actually positive for the reintroduction of the Mauritius Paradise Flycatcher and Mauritius Cuckoo-shrike since these birds are more affected by rats than mongooses. But we would still need to carry out predator control to reduce their number further. More predators were generally recorded in the wet season compared to the dry season. Predators (Cats, Mongooses and rats) can be reduced further by sustained predator management and this would need to be carried out before any bird re-introduction is attempted.

The gecko study showed that were no difference in the number of geckos present in the Ferney Valley and sites were the Cuckoo-shrike are surviving. This is positive for the reintroduction of the Mauritius Cuckoo-shrike, which feed on geckos and insects.

This study showed that Ferney had more rainfall compared to the actual distribution of the birds. But this could be skewed due to lot of rains in November. However, the temperature did not vary significantly between Ferney and the current distribution of the birds.

Conclusion

The focus of this study was to investigate the feasibility of establishing a new sub-population of Mauritius Cuckoo-shrike and Mauritius Paradise Flycatcher in Ferney Valley. Habitat suitability, invertebrate diversity and densities, gecko diversity, predator diversity and climatic conditions in the Ferney Valley were investigated alongside a comparative study of Black River Gorges National Park sites, which maintains the last remaining strong-hold of both birds. The study was supportive towards Ferney Valley being a suitable re-introduction site for the Mauritius Cuckoo-shrike and the Mauritius Paradise Flycatcher. There were however, some differences in terms of habitat preference, invertebrate, predator, gecko densities and climatic conditions. These were not seen as an obstacle to the re-introduction of these two bird species. We thus suggest that trial releases for both species be carried out in Ferney. But we advise that rigorous post release monitoring is carried out to ensure that the released bird are settling in well in their new environment. We can plan and predict the success of re-introduction, but the only way to know if it is successful, is to trial it.

Ultimately this project does not solely concern conservation of the Mauritius Cuckoo-shrike and Mauritius Paradise Flycatcher, of which there is considerable need, but also the restoration of Ferney Valley. Whole ecosystem restoration is often overlooked in conservation efforts today, with many organisations focusing upon priority species (Hutton *et al.*, 2007). Ongoing efforts to restore Ferney Valley should not only consider habitat restoration, but also the need to replace species that fit a lost or missing ecological role. It is likely that the many land bird species which were once abundant on Mauritius (Jones, 1996) fulfilled a valuable and important role in the ecological processes needed to maintain the unique environment that previously existed. Small passerines may have provided several of these ecological roles, such as acting as natural pollinators, seed dispersers and trophic regulation. Creating an additional population of Mauritius Cuckoo-shrike and Mauritius Paradise-flycatcher would not only secure the future survival of these threatened passerines, but may also assist in habitat regeneration in Ferney Valley.

Habitat Restoration Recommendations

It may be wise to increase habitat restoration that is supportive of the reintroduction of the Mauritius Cuckoo-shrike and Mauritius Paradise Flycatcher. However, it may be necessary to temporarily maintain some introduced non-invasive species in place until the native forest recovers so as not to leave large barren areas that would not be able to support birds. These trees could provide perches for birds, shelter, and possibly food in the interim.

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