



Fiji Terrestrial Report 2019



Edited by Dr. Jane Hardwick

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Research Team and Forest Guides

Research Team

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Fijian Survey Guides

David – Head Guide and Carbon/Habitat Guide (left picture)

Tui – Carbon/Habitat Guide

Tui (King) – Arachnid/Invertebrate Guide

Vosa – Arachnid/Invertebrate Guide

Maika – Butterfly Guide (right picture)

Bill – Bird Guide (middle picture)



General Introduction

Island habitats are particularly vulnerable to environmental changes; at least 75% of all known extinctions since 1600 AD have occurred on oceanic islands, in particular this has affected birds and amphibians. One of the main causes of these extinctions is the introduction of non-native invasive species (Groombridge *et al.* 2002). It is well documented that the introduction of invasive species (including rats, cats, pigs, mongoose and cane toads) to Fiji has caused huge losses to native biodiversity (Morley 2004; Morrison *et al.* 2004). In particular, the mongoose (*Herpestes javanicus*) are opportunistic feeders feeding on a variety of food types including lizards, frogs, toads, birds, invertebrates and plants (Gorman 1975). It is thought that they are one of the key drivers of the decline in many herpetofauna and bird species in Fiji, in particular, the banded iguana (*Brachylophus* spp.) and Fiji's only endemic amphibians – the Fiji ground frog (*Platymantis vitianus*) and the Fiji tree frog (*Platymantis vitienus*) (Morrison *et al.* 2004). The issue of the mongoose, coupled with extensive deforestation and land-use change have caused rapid biodiversity loss to Vanua Levu and many of the other Fijian islands (Olsen *et al.* 2006).

The Fijian archipelago consists of approximately 320 islands, of which Viti Levu and Vanua Levu are the two largest. The Fiji Islands are volcanic and have a unique flora and fauna including an entire family of plants (Degeneriaceae), two species of iguana and an endemic snake genus (Ogmodon). The proportion of endemic plants, however, is debated due to controversies in the number of endemic plants but between 25-63% of vascular plants are endemic (Ash 1992; Smith 1996). Furthermore, 40 % of herpetofauna species are endemic and another 40% are considered native (Morrison 2004). There are also 31 endemic species of bird (Lepage 2020). The Natewa Peninsula is 60km long and makes up the south-eastern section of Vanua Levu. The landscape across the peninsula is rugged, with steep forested hills. Extensive logging was carried out across the lowland areas of the peninsula from 1969 to 2000 (Masibalavu and Dutson 2006; Powling 2018). There is only one protected area on Vanua Levu, a 120ha area called Waisali Forest park, but it is proposed that the Natewa Peninsula should be designated as a National Park, to prevent further damage to this unique environment (Powling 2018). Taveuni Island, which lies only 6.5km to the east of the peninsula and is of similar size and boasts three large protected areas totalling 16,685ha. Taveuni's native wildlife has also been protected from the invasive mongoose, which do not yet occur there (Morley 2004). In the future, it is hoped that Operation Wallacea survey teams can collect data in Taveuni to make biodiversity comparisons to the Natewa Peninsula.

Research Objectives

For Operation Wallacea's third season of surveys in Vanua Levu Fiji, a combination of biodiversity and carbon data were collected across the Natewa Peninsula throughout the months of June and July 2019. This report summarises the data gathered by the scientists and students who assisted with field surveys. Operation Wallacea's Fiji forest base camp is comprised of a tented camp alongside an abandoned Forestry Cabin in the centre of the Natewa Peninsula. The surveys carried out provide biodiversity data which can be used as a guide to determine the biological value of the Natewa Peninsula, with the primary goal being able to prove the peninsula is an area of great conservation importance and implementing a "National Park" level status to protect the land from land-use change amongst other threats (Powling 2018).

This report will detail the findings from the 2019 data collection and show comparisons to previous years where possible. However, comparisons must be taken with caution due to factors such as changes to climate or different surveyors using slightly different techniques. Furthermore, as there are only three seasons worth of data for Fiji so far, it is too early to make any reliable temporal conclusions. However, these data can be used to compile species records and for spatial analyses across the landscape.

The overarching aim of the research carried out across the Natewa Peninsula is to provide a biological value of the peninsula by estimating the amount of carbon stored in the forests and by identifying the biodiversity, and, in particular, gaining a better understanding of the ecology of species that are endemic to the peninsula area. More specific aims for this year's fieldwork were:

- To collect carbon measurements for approximately one hundred 20 x 20m forest plots across the peninsula and classify forest types where surveys are carried out
- To resurvey all bird transects from previous years, and to add new bird survey sites so that bird biodiversity can be measured across the peninsula and monitored yearly
- To assess the distribution and ecology of the Natewa silktail (*Lamprolia klinesmithi*) (endemic to the peninsula), the orange dove (*Ptilinopus victor*) and the maroon shining parrot (*Prosopeia tabuensis*) (both endemic to Vanua Levu and offshore islands).
- To investigate Arachnids communities at each bird survey site across the peninsula
- To measure 20 x 20m habitat plots at each bird and invertebrate site, to understand the main factors that are driving their biodiversity
- To survey the butterfly communities across the peninsula and to update the species record list
- To increase knowledge about the ecology and behaviours of the Natewa swallowtail (*Papilio natewa*) (a new species of butterfly discovered by Opwall teams in 2018)

Maps



Figure 1. Map of Fiji Islands (not all shown) and location of the Natewa Peninsula (shaded area) on Vanua Levu.

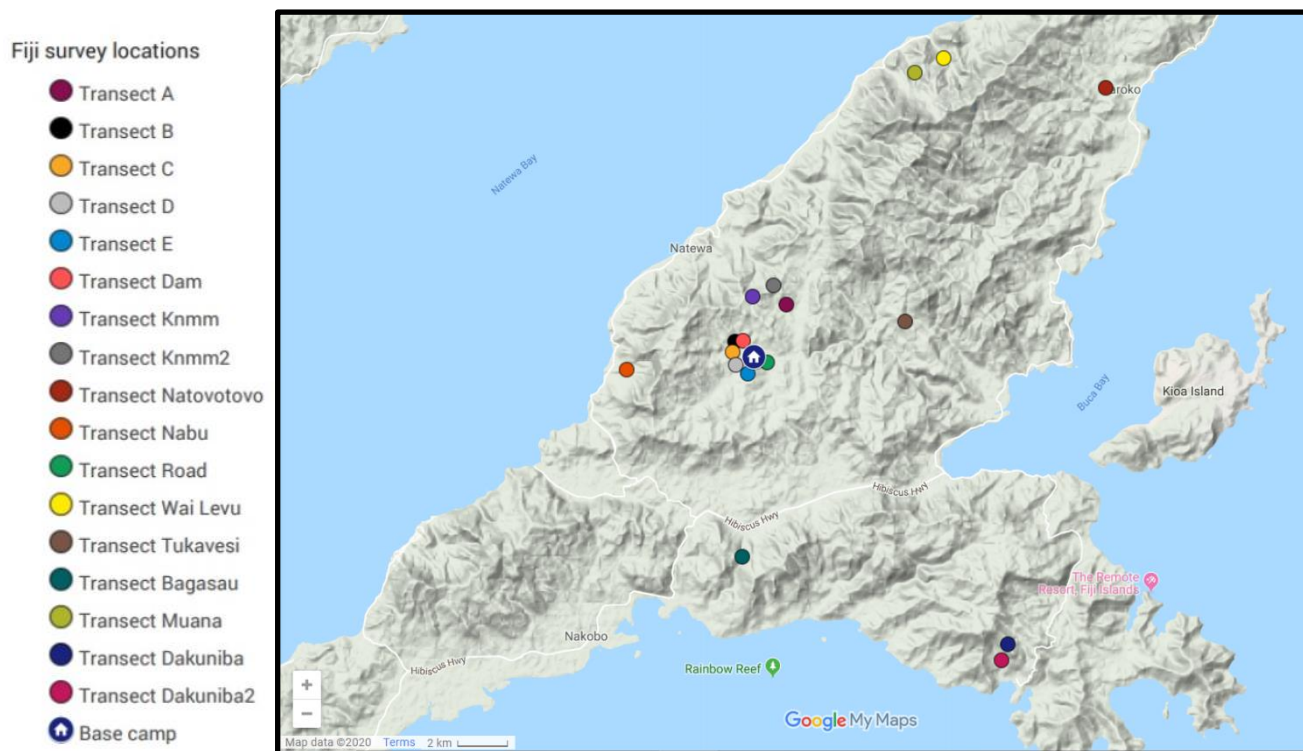


Figure 2. Map of survey sites on Vanua Levu. Each coloured dot represents six survey sites.

Habitat and Carbon Report

by Joe Salmona, Rachael Thomson and Jane Hardwick

Introduction

Since the development of modern agriculture, humans have had a complex relationship with the world's forests. Between the seventeenth and nineteenth centuries, temperate forests in the Americas and Australasia were logged heavily as a result of European expansion, resulting in the depletion of tropical forests (Smith and Borocz 1995). Tropical forest destruction not only has local consequences but can also have global consequences. On a local level, deforestation and forest degradation can cause changes in climate, physical and chemical soil properties, and hydrological disturbances (Cramer *et al.* 2004). Deforestation on a great scale can change albedo and atmospheric water balance could affect regional weather patterns (Lawton *et al.* 2001). There are concerns that deforestation can contribute to atmospheric warming from the addition of carbon dioxide into the world's atmosphere from biomass burning or decomposition (Fearnside 1996). Arguably, the greatest problem that results from destroying tropical forests is the unprecedented loss of biological diversity within tropical forests (Gibson *et al.* 2011). Our understanding of numbers, distribution and status of tropical ecology is extremely limited. To combat the large knowledge gap, further research is required and a conservation solution is to preserve much of the remaining forests.

The Pacific has high terrestrial biodiversity and endemism including more than 30,000 plants and 3,000 vertebrates (Mittermeier *et al.* 2004). Much of this unique biodiversity is poorly understood and has little protection. Pacific nations have relatively little funding from the government or environmental organisations. This has led to habitat loss and degradation being leading causes of tropical forest loss in the Pacific. To help resolve the biodiversity loss, developed countries have funded and implemented local conservation initiatives with non-governmental organisations (NGO's). Despite these efforts most conservation programmes have been unsuccessful in reducing biodiversity loss and environmental degradation has continued at a steady rate in some Pacific countries with 0.15% of total land area and less than 20% of discovered ecosystems are in designated protected areas (Chape *et al.* 2003). Ma *et al.* 2013 suggests the poor conservation outcomes are attributed to differences in land ownership, cultural, economic and social differences. They suggested that increased landowner involvement, alternative income generating activities, stakeholder understanding/collaboration, improved conservation funding management would greatly improve conservation efforts in the region.

To address the current conservation issues in Fiji, Operation Wallacea established a project in 2017 within the Natewa Peninsula on the second largest Fijian Island (Vanua Levu). One of the main aims of the project is to categorise different forest types in the area and record the amount of forest carbon to collaborate with the REDD+ scheme in Fiji (The REDD Desk 2020). By working with local Mataqali landowners, stakeholders and prioritising the integration of the local people and the local economy Operation Wallacea wishes to establish a National Park designation in the area. The designation of the National Park will ensure that the protection of Fiji's endemic birds, plants, herpetofauna, invertebrates and marine life will have the necessary protection. Additionally, by surveying forest habitat and carbon plots throughout the peninsula and involving REDD+ scheme funding, the protection of the forest and the local economies will be ensured. Following on from previous years the aims included bringing the total number of carbon plots to approximately 100 (29 were completed previously) across a range of habitats to make a more accurate estimate of carbon stored in

different forest types. Additionally, habitat data were collected to use alongside the biodiversity surveys to determine which factors were important for different species.

Methods

The study was conducted on the second largest island of the Fijian archipelago (Vanua Levu) on the Natewa Peninsula which covers an expanse of 55,000 ha (Figure 1). The area is covered by craggy lowland and hill forest extending from 800m to sea level. Land across the peninsula is owned by at least 30 landowning units (Mataqali) across more than 16 villages (Ravuso, 2013).

Habitat and carbon plots were surveyed over an eight-week period in June and July 2019. At each site shown on Figure 2, six sample plots (20mx20m) were surveyed along a 1km transect 200m apart. In order to obtain a representation of forest across the peninsula, survey sites were selected based on the level of forest disturbance, degree of slope and distance from human habitation. Within the quadrats, circumference at breast height (CBH) was measured for trees, poles and saplings. Trees were measured at a $cbh > 47\text{cm}$, poles $< 47\text{cm}$ and $> 16\text{cm}$ and saplings $< 16\text{cm}$. CBH was measured at 1.3m above ground level unless there was buttressing or nodules at this height. Along the cross section of the quadrat, canopy cover was estimated every 1m along the intersecting tapes starting at the south end of the south-north tape and then beginning again at west to east. This measure was counted using a 25cm by 25cm clear perspex square with 25 dots and the number of dots in light gaps was recorded. Density of woody plant species was measured using a 3m pole separated into metre segments, whereby the number of woody plant species were recorded at each metre. Elevation change from the lowest point of the quadrat to the highest point was measured using a clinometer. Tree species were recorded alongside tree measurements. For the trees ($CBH > 47\text{cm}$) observed in each plot, a MS Excel spreadsheet was used to convert CBH into diameter at breast height and then feed into our allometric model for tropical lowland forest to give a total carbon value in kg for each the plot.

Results

Following on from a successful 2018 season, the fieldwork program was expanded to new forests in new parts of the Peninsula in 2019. A total of 83 and 84 sites were surveyed for habitat and carbon stocks, respectively, in 2019. This brought the total number of plots across the peninsula to 113 (carbon plots) and 112 (habitat plots), which surpassed our goal of reaching 100 plots. With the assistance of two local guides, David and Tui, both in their 3rd season with Operation Wallacea, we have a high degree of confidence in the identification and translation of local tree species. The majority of sites surveyed in 2019 were categorised as either undisturbed primary forest (32%) or disturbed (logged, 35%), with the remainder being categorised as edge plots (9%), plantation (9%) or road (15%).

As can be seen in Figure 3, the majority of plots measured had a carbon stock of between 5,000kg and 25,000kg. At the individual plot level, we found that the average carbon stock was 14,470kg (median=9,867kg, std error=2,223kg, $n=84$) with a high degree of variability due to outliers. There was one plot that had no carbon according to our model as no trees were recorded -Transect D Point 1 on an old logging road. The site with the second lowest carbon was Transect D Point 2, also on an old logging road, with 536kg of carbon. However, we increased our largest value for carbon stock in a single plot from 60,389kg in 2018 to 143,960kg in 2019. This was recorded at Dakuniba Transect A Point 3. The second largest value for carbon, 123,601kg (Nabu Point 4) was recorded in close proximity to the marine

site.

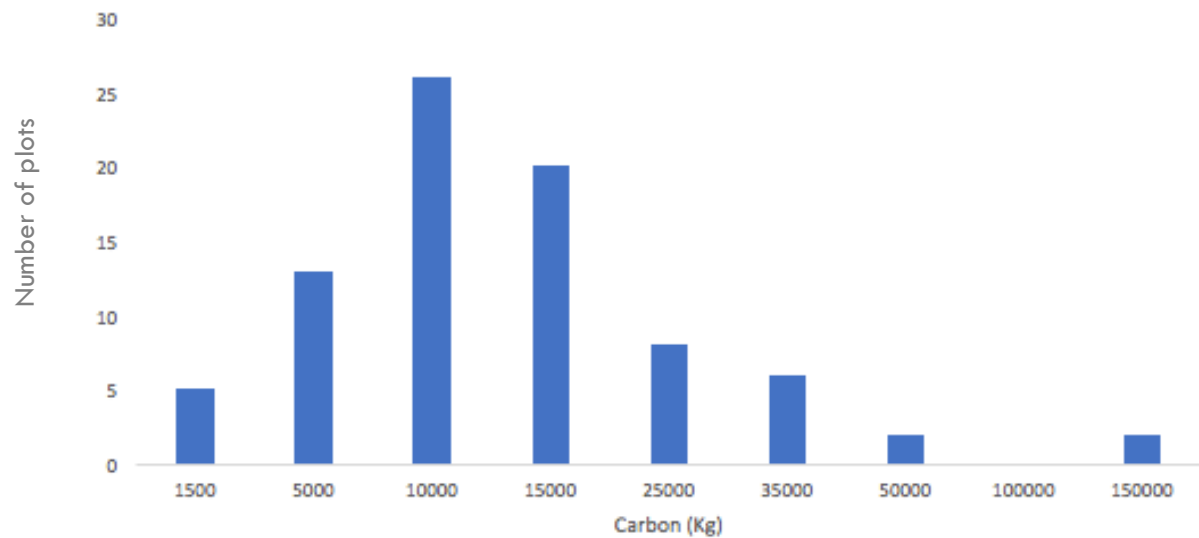


Figure 3. Average carbon recorded per plot across the Natewa Peninsula.

At the transect level, the transect that recorded the highest average carbon value was Nabu (38426.8kg per site) closely followed by Dakuniba Transect 1 and Bagasau. These sites also had high relative standard error due to outliers. The sites closest to Base Camp, which previously served as a logging camp, had the lower average carbon values than transects in more remote locations (Figure 4). These values tended to be consistently lower as shown by their smaller standard error. As observed by students and scientists alike, the transects around Base Camp were heavily disturbed and at times during the season we interacted with heavy machinery and farmers during surveys. The more remote sites that were difficult to access for research are typically more difficult to reach with heavy machinery and are less likely to be disturbed.

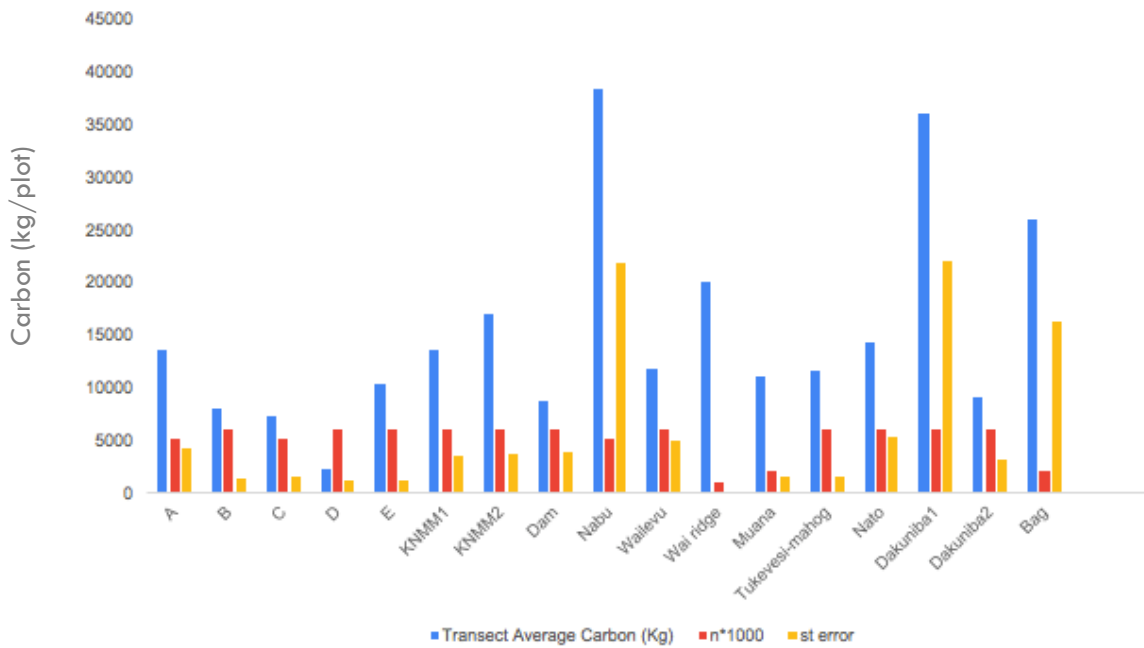


Figure 4. Average carbon recorded per six-plot transect across the Natewa Peninsula.

When testing for correlations between amount of carbon (per plot) and other habitat variables (using Pearson's test if data were normal and Kendall's tau for non-normal variables), carbon was negatively correlated to canopy scope readings and the amount of disturbance to plots and positively correlated to total saplings and total trees (Table 1 and Figure 5 A- D). No correlation was found between total number of poles per plot and amount of carbon recorded. Outliers were removed from data for these tests.

Table 1. Habitat variables tested for correlation with total carbon (kg/plot), test used (based on whether data were normal or not normal) and p-values.

Variables	Test	P-value
Total carbon and canopy scope	Kendall's tau	0.002*
Total carbon and total saplings	Pearson's correlation	0.02*
Total carbon and total poles	Pearson's correlation	0.7
Total carbon and elevation	Kendall's tau	0.4
Total carbon and disturbance level	Kendall's tau	<0.01*

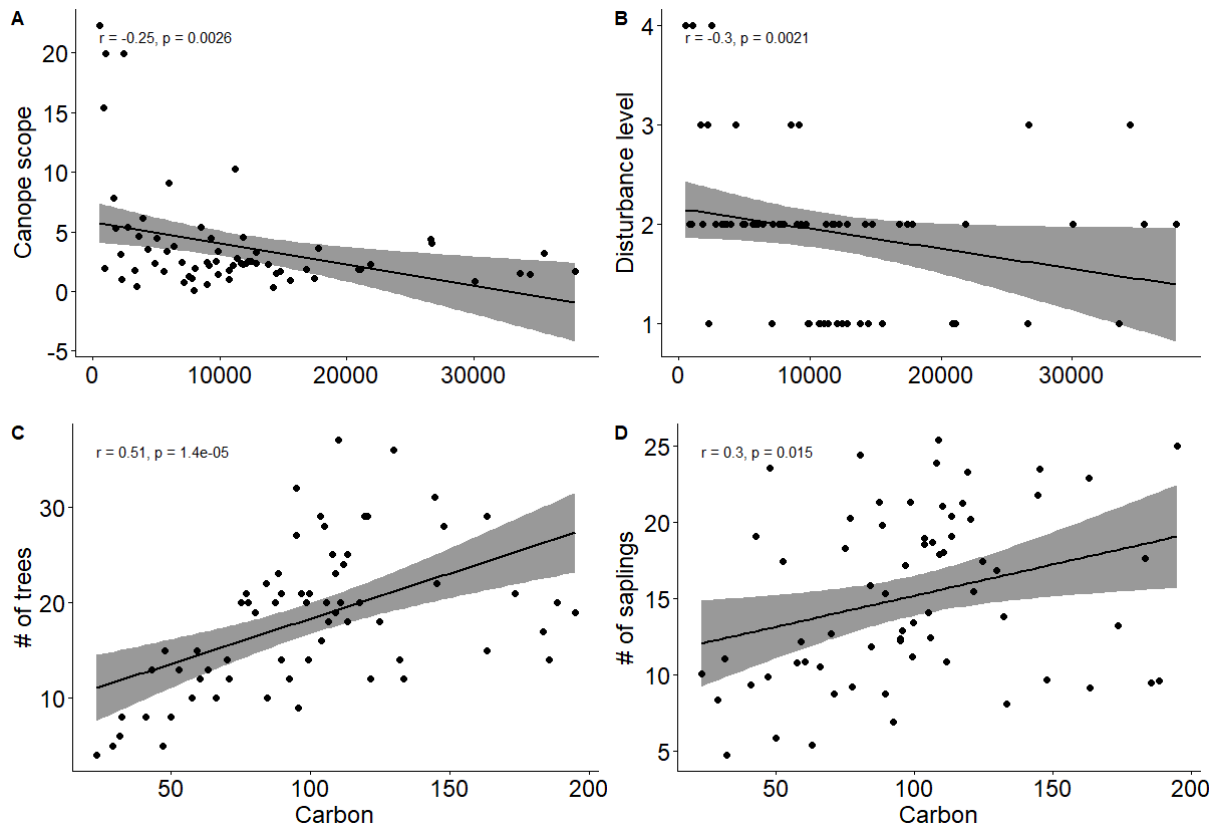


Figure 5. Significant relationships shown on scatter plots between total carbon (kgs per plot) and A) mean canopy scope 'light' reading, B) disturbance level (on a scale of 1 to 4, where 1 is least disturbed and 4 is very disturbed), C) total number of tree, and D) total number of saplings.

Discussion and Future Recommendations

The 2019 field season was successful as it successfully built on the data collected in previous years. The Forest Team were able to leverage improved relationships with Mataqali landowners to survey new areas of the peninsula and build a greater picture of the health of the forest. The results show that we were able to find some trends between habitat variables, showing that the more disturbed habitats (that would have greater canopy scope 'light' readings and less trees) were indeed the plots with the least carbon. However, more plots in a greater variety of habitat types are needed to improve our understanding of habitat and carbon storage in Natewa. Accessing more remote and isolated forests which are less likely to have been disturbed is vital in determining the true carbon storage of the Peninsula and will be hold key habitat data that can be used by our other science teams. Moving forward we hope to use remote sensing to classify the forest types across the peninsula and try to build an accurate picture of the state of the forests and how much carbon is sequestered in the forest. As noted in previous years, one of the major reasons for habitat loss across the peninsula is for that of kava farming. Although small scale, farmers are gradually moving deeper into the forests to clear patches of land to grow kava. It is the most profitable legal crop for landowners but sadly is accompanied with unsustainable land clearance with excessive use of agrochemicals (IBP USA, 2010). Therefore, effort is required to educate communities on the detrimental effect of land degradation, particular slash-and-burn agriculture across the peninsula, particularly in locations of important biological significance.

Ornithological Report

by Joe England

Introduction

The Natewa Peninsula is hugely important in terms of its bird life, as it is with many other taxonomic groups. Geographically, the peninsula is a near island and is host to many endemic species which have adapted and evolved as part of a unique ecosystem. Almost half of the country's terrestrial birds are only found in Fiji, making it a country with one of the highest rates of endemism in the world. One such endemic species, the Natewa silktail (*Lamprolia klinesmithi*), exists only on the peninsula and remains an enigma in terms of its ecology (England 2019). The area is also a significant stronghold for other endemics such as the orange dove (*Chrysoena victor*) and maroon shining parrot (*Prosopiea tabuensis*). Despite the presence of these highly specialised species, there is a distinct lack of data on the ecology, population dynamics and morphology of the peninsula's avifauna. An Important Bird Area (IBA) was setup in recognition of the areas importance but this only exists as a line on a map and does not present any legal protection. Although community agreements on land-use were initially made, small-scale farming persists and is increasingly encroaching inland, degrading mature forest and its associated biodiversity. The Operation Wallacea project is tackling each of these issues by involving local communities in the expedition and presenting scientific research as part of a proposal for a national park. This report aims to summarise the findings from 6 months of ornithological fieldwork across 2017, 2018 and 2019, increasing our understanding of the areas avifauna and informing practical conservation.

Methods

There are two main elements to the bird survey work; point counts and mist netting. Point counts were the main form of survey, to gain a good understanding of species presence, abundance and relationship with habitat. The methodology for point counts was refined in the second year and so the data in this report only compares the findings from 2018 and 2019. Every morning a transect would be conducted (see Figure 2 for transect locations) as long as it was not raining heavily, or the wind was not too high. Generally, point one of a transect was on the road or logging road (mud track) and would work its way into the forest. Each transect consisted of six points, 200 metres apart. The first point would be surveyed as close to dawn as possible (06:00am), with the transects being done in reverse occasionally to remove any time bias along the disturbance gradient. At each point all bird species seen or heard were recorded for ten minutes, the maximum number heard or seen at one time and the distance from observer estimated (0-25, 25-50, 50-100 and 100+ metre bands). There was no settling down period before the count was started. Detailed 20x20 metre forest structure and carbon plots were also carried out at each of these points to accurately determine and categorise habitats, this data is not used directly in this section of the report but will be utilised in future research papers. Instead, an overall disturbance level was assigned to each point, by the senior scientist (JH) and myself (JE) based on our first-hand observations.

Mist netting was carried out at eight sites, four of which were repeated each year to maximise the recapture rate. Sites were netted for one or two weeks with the maximum number of available nets, usually six 10x3 metre nets. Nets were checked every 30 minutes and any birds caught were extracted, bagged and taken back to a temporary ringing station. Every bird caught was ringed using New Zealand rings, with the species, age, sex and any moult being

identified if possible. The weight, wing, head-bill, tarsus and tail lengths were measured before releasing the bird. In 2019, any Silktails caught were also ringed with a combination of two colour rings on the alternate leg to the metal ring.

Results

Bird species abundance and diversity

A total of 51 species have been recorded on the peninsula across the three years, 17 of which are endemic to Fiji. A full species list is included as Supp. Mat. Table S2. A total of 31 species were observed on point counts, which included 29 species from 18 surveys in 2018 and 30 species from 20 surveys in 2019. Average abundance per point was calculated for each of these species for each year, see Figure 6. The most common species was barking pigeon (*Ducula latrans*) followed by Fiji whistler (*Pachycephala vitiensis*) and then maroon shining parrot (*Prosopeia tabuensis*), Fiji bush warbler (*Horornis ruficapilla*) and sulphur-breasted myzomela (*Myzomela jugularis*). Eight of the ten most common species are endemic to Fiji. The abundance for most species was very similar between 2018 and 2019, as was the average number of birds recorded per point (15.56 in 2018 and 15.12 in 2019).

Using the Shannon Wiener Index (H), the diversity at each point across the two years was calculated and then compared with the disturbance level (mature forest = 1, regenerated forest = 2, disturbed forest = 3 and road = 4), see Figure 7. This showed the least disturbed forest held the highest average diversity (2.16) and the most disturbed habitat held the lowest average diversity (1.95), the intermediate forest types did not fit the trend (regenerated forest 2.01, and disturbed forest 2.11).

Species accumulation

Netting hours were fairly comparable across all years, as was the number of species caught (2017; 334 hours and 11 species, 2018; 298 hours and 10 species, 2019; 299 hours and 12 species). The species accumulation curve was also very similar year to year, all having a similar gradient throughout and reaching a near asymptote at the same stage of netting effort (Figure 8). Despite similar curves and netting effort, in 2019 less than half the number of birds were caught than in the previous two years.

Key species and disturbance level

This analysis only assessed birds recorded within 50m of the observer to improve the accuracy of comparisons between species and habitat and it focuses on the three species endemic to Vanua Levu and its offshore islands. The average abundance of Natewa silktail was negatively correlated with disturbance level, density was greatest in mature forest and lowest on the road and disturbed forest (Figure 9). Maroon shining parrot and orange dove were both most abundant in regenerated forest, the maroon shining parrot thereafter showing a preference for disturbed forest and the orange dove for mature forest (Figure 9). Rough population estimates calculated the number of Natewa silktail on the peninsula at 3895, orange dove at 15,791 and maroon shining parrot at 11, 671 (Table 2).

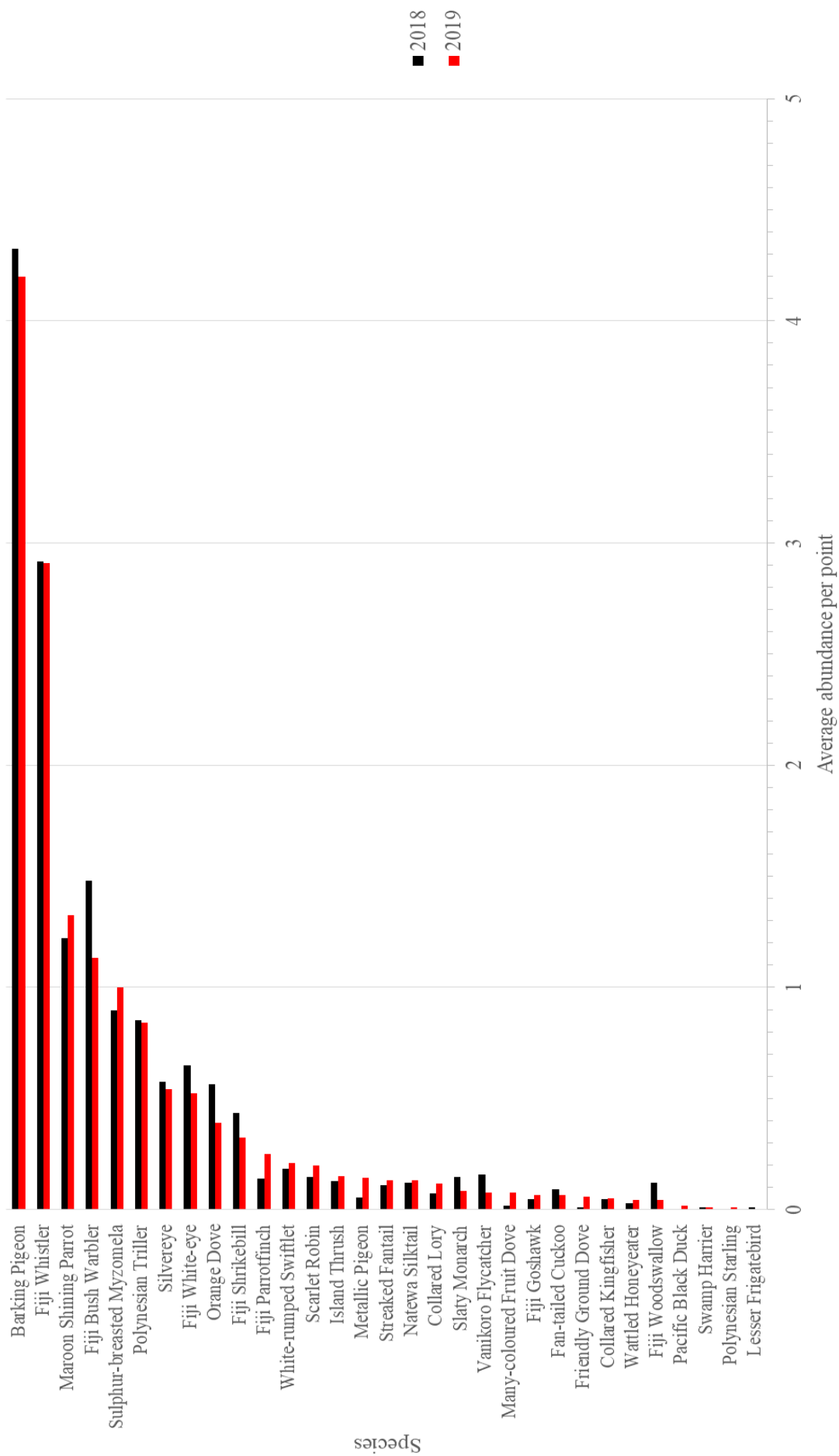


Figure 6. Mean bird species abundance per point count for years 2018 and 2019.

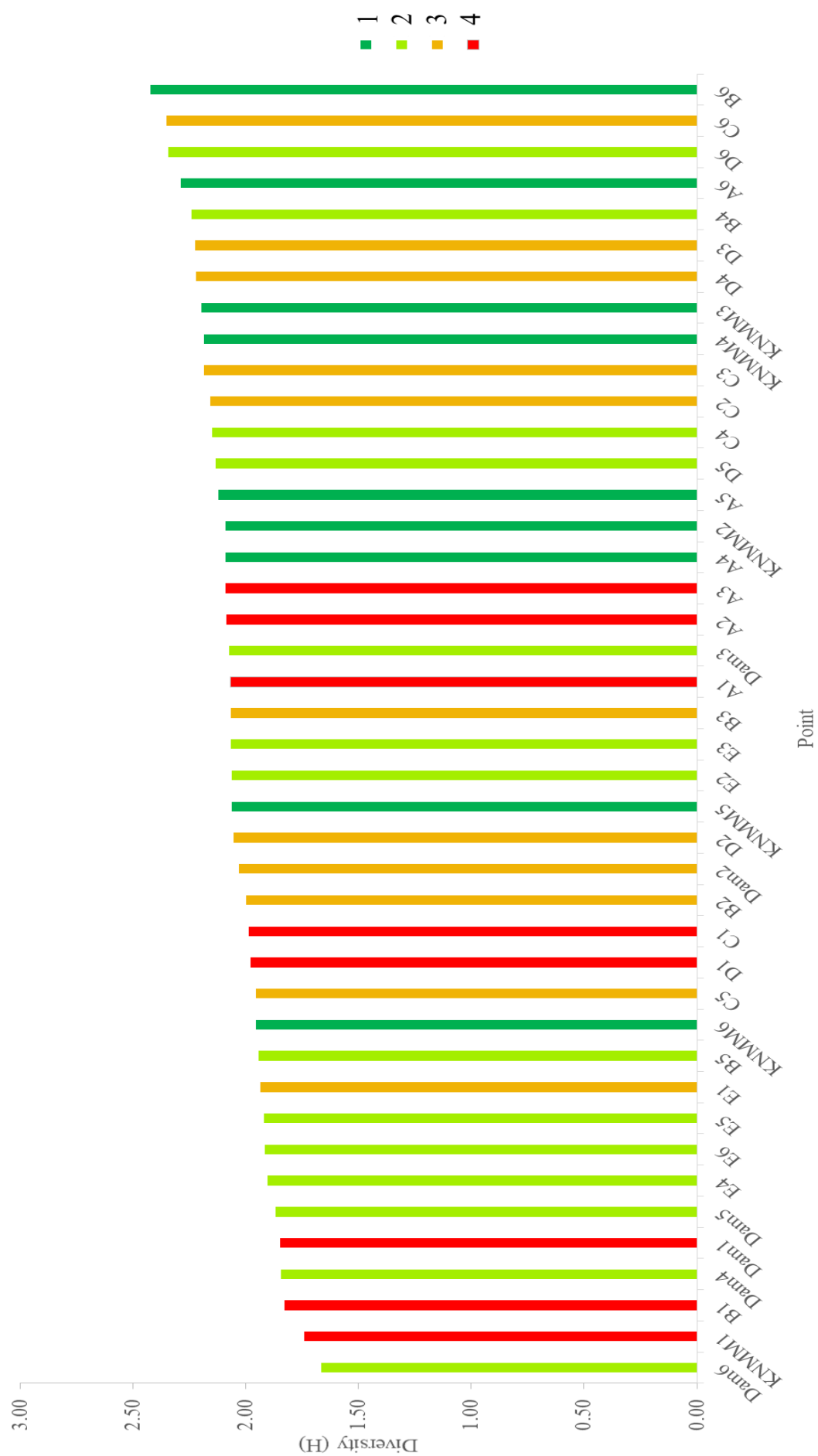


Figure 7. Diversity (H) of each transect point surveyed, with the disturbance level of each point displayed by colour. Dark green = Mature forest, Light green = Regenerated forest, Dark yellow = Disturbed forest, Red = Road.

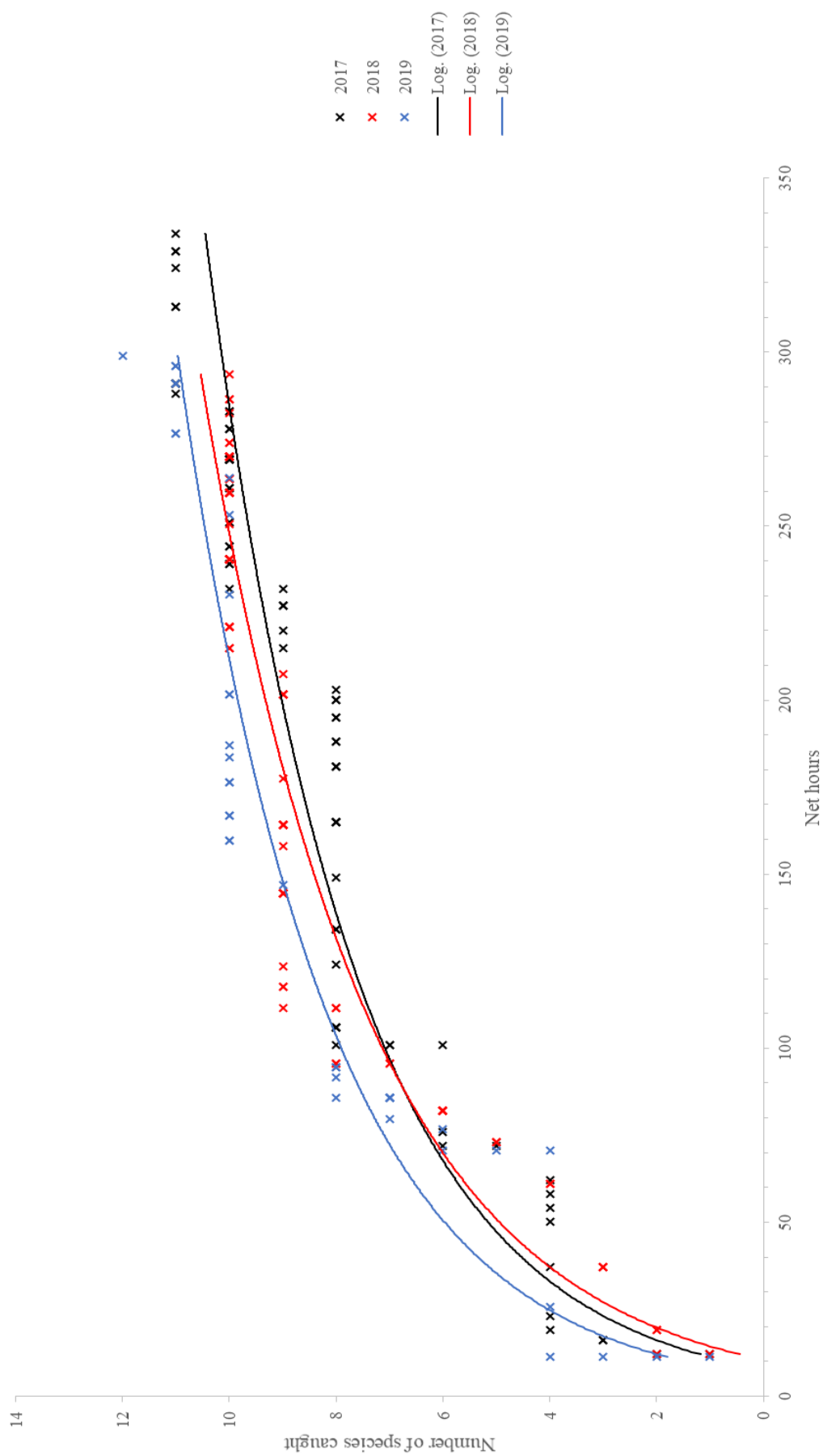


Figure 8. The number of species caught each year with increased netting effort. Species accumulation curve for each year plotted using a logarithmic curve.

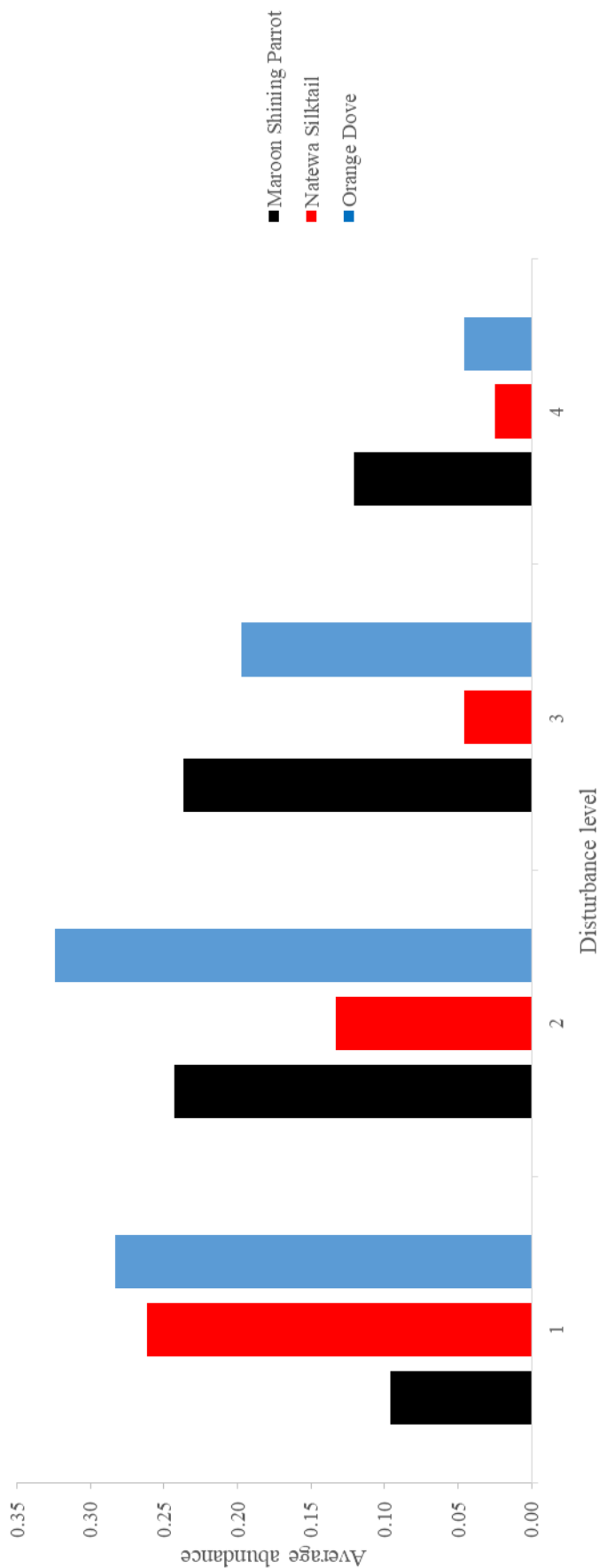


Figure 9. The average abundance across different levels of disturbance for three key species; maroon shining parrot (*Prosopeia tabuensis*), Natewa silk-tail (*Lamprolia klinesmithi*) and orange dove (*Chrysoena victor*).

Species	Total seen	Surveys	No. of points	Points present	Points present (%)	Avg. per point	Point area (m2)	Distribution (m2)	No. of points across distribution	Population est.	Natewa Population est.
Natewa Silk-tail	36	306	102	24	23.53	0.12	7853.98	260000000	33104.24	3894.62	3894.62
Orange Dove	69	306	102	37	36.27	0.23	7853.98	1320000000	1680676.55	378976.08	15790.67
Maroon Shining Parrot	51	306	102	30	29.41	0.17	7853.98	2400000000	3055775.54	509295.92	11671.36

Table 2. Workings to estimate the population size of the three key species.

Discussion

Species abundance and diversity

Despite the relatively low bird species richness, the finding that eight of the ten most common species are endemic suggests the peninsula is an incredibly unique and valuable ecosystem. The five most common species represent a cross-section of the feeding guilds you would expect to find in a tropical forest system. Outside the more common species however, abundance of rarer species is incredibly low. Given that the peninsula is a near-island, it is appropriate to apply island biogeography theories to explain the overall low avian diversity (Wilson & MacArthur, 1967). The similarity in the overall abundance of birds and each species detected from 2018 to 2019 shows no significant annual trend. If a trend is present, however, it is more likely to be identified after a third year of surveying and improve with each consequent year. By collecting a longer term dataset, the overall health of the ecosystem and on individual species population trends can be better understood.

Disturbance level predicted bird diversity at the two extremes of the scale, but not at the two habitats with mid-level disturbance which showed the reverse of what would initially be expected. The first point to make is that small scale disturbance can have a positive impact on diversity, particularly species associated with forest edge and dense secondary growth (Forsman, *et al.*, 2010). Disturbance also catalyses the introduction and effects of invasive species which may outcompete important native species (Murphy & Romanuk, 2014). A good example of this, is to look at the effects of disturbance on the Natewa silktail (Figure 9), which shows an obvious preference towards the least disturbed forest.

Secondly, the habitat categorisation at this stage has been very roughly ascertained. This is made more difficult by the varied past land-uses across the peninsula. The traditional agricultural system involves a new small plot of land being distributed to families every four years to be cleared and cultivated (Cegumalua *in pers. comm.*, 2019). Add to this, logging activity, pine and mahogany plantations (Masibalavu & Dutson, 2006) and you are left with a complete mosaic of habitats at various stages of regeneration. The small remaining fragments of seemingly primary forest are limited to higher altitudes and along protected water courses. Once analysis has been conducted on the forest structure and carbon data, better categorisation and delineation between forest types can be ascertained and provide more of an insight on the relationship between diversity and disturbance.

Species accumulation

The similarity of all three species accumulation curves suggests again no significant difference in species richness year to year at the mist-netting sites. Near-asymptotes after 250 hours show the mist-netting is capturing a representative and almost-complete picture of the species that are occupying the lower stories of the forest. Mist-netting is not going to detect many of the species occupying the canopy and upper story of the forest (Martin, *et al.*, 2017) and our results show that this method only captured 51% of the species recorded on our point counts. This indicates that increased net-hours would not glean many additional species. The low species richness and the lack therefore of many cryptic, understory species makes the mist-netting a fairly ineffective method when it comes to monitoring biodiversity on the

Natewa peninsula. Instead mist-netting should be focused on maximising recaptures, learning more about species life history, morphometrics and local movements.

Key species

The strong correlation between Natewa silktailed abundance and habitat disturbance follows what is known about the ecology of this enigmatic species (BirdLife International, 2017; England 2019). Although it was recorded in disturbed habitats and mahogany plantations, these points were always in close proximity to mature forest and it seems the species is heavily reliant on this undisturbed habitat. These patches of mature forest are vital to the breeding ecology (England 2019) and therefore essential for the survival of the species. The population estimate reported here is a significant and worrying reduction on the previous estimate of 6,000-12,000 individuals (BirdLife International, 2017), which is based on very little available evidence and 20 years out of date. Despite the implementation of the IBA and community initiatives, mature forest continues to be degraded through agricultural and logging practices (BirdLife International, 2017). The combined factors and threats highlighted here should spur on increased monitoring of the species and formal protection of remaining tracts of mature forest.

The orange dove showed a preference for less disturbed habitats but favoured regenerated over mature forest. It was previously thought this species was not present in disturbed landscapes (BirdLife International, 2016) and so this information sheds new light on the distribution and tolerance levels of this endemic bird. The maroon shining parrot's broad habitat utilisation is fairly well documented (BirdLife International, 2018), however it is surprising to see it favoured all disturbed habitats over mature forest. Often frugivorous species are abundant in partially disturbed habitats as these areas have an increased density of fruiting trees (Marsden & Pilgrim, 2003). The maroon shining parrot in particular is known to feed on a wide range of fruiting tree, including non-native species (Collar & Boesman, 2020) which are more likely in anthropogenically altered landscapes. This evidence shows that forest clearance, if regeneration is allowed, can increase the food availability for frugivorous species. Other life history traits of these species may require mature forest, nest-site availability for example is generally greater in old growth forest (Marsden & Pilgrim, 2003), and so care should be taken to encompass all ecological aspects when applying practical conservation measures.

No population estimates exist for either the orange dove or maroon shining parrot, so the estimates made here are the first indication of the species' overall condition. The Natewa peninsula, given its comparatively healthy ecosystem, is thought to be a stronghold for the orange dove and maroon shining parrot (Kerr, 2018), yet they occur across Vanua Levu and some of its nearby offshore islands. The population estimate for the Natewa peninsula is likely to be more accurate than the total estimate, as the estimates are based on extent of occurrence rather than area of occupancy. A species is unlikely to occur throughout the extent of occurrence, which may contain unoccupied or unsuitable habitat. Nevertheless, these estimates are a good starting point and are a promising indicator for the health of both species.

Silktail captures

The fact that 80% of adult birds showed signs of breeding shows that June and July are certainly peak breeding season, the predominance of males would also corroborate this as the females would be sitting on the nest. It is interesting that all recaptures were adult males, suggesting it is the males that hold down the same territory year on year (Supp. Mat. Table S1). The colour rings will now allow a better understanding of movement, breeding and behaviour of the different sexes and individuals. A generation length of 4.2 years has been estimated but is not based on any evidence (BirdLife International, 2017), making the bird recaptured in 2019 the longest known living Natewa silktail, at three years plus. A better longevity record will hopefully be recorded in subsequent years. The normal distribution of weight, head bill and wing all confirm that these features are not sexually dimorphic. The variation seen in tarsus length could be due to some split in the population, as could the range in tail length measurements (Supp. Mat. Figure S1). However, this variability could be down to measurement error both within and among observers across years (Goodenough, *et al.*, 2010).

Other significant findings

Yellow-billed honeyeater

Rachel Hufton observed a population of this species on the south-eastern limb of the Natewa peninsula, around Dakuniba (Figure 2), although no photographic evidence was recorded. The previously thought absence of both this species and the chestnut-throated flycatcher (*Myiagra castaneigularis*) (previously considered conspecific with *Myiagra azureocapilla* on Taveuni) from the peninsula has long mystified naturalists. Both occur on the rest of Vanua Levu and Taveuni and set Natewa apart in yet another ecological way. The discovery of yellow-billed honeyeater at Dakuniba would be an interesting range extension and add to the intrigue surrounding the small-scale differences in bird communities and niche occupation in the area.

Friendly ground dove nests

Two nests of this vulnerable species were found at Nabu, in some of the last remaining mature coastal forest on the peninsula. The first nest was around 2m high with two young chicks which looked to be only a couple of weeks old. The second was at a similar height but with one white egg in the nest.



Two friendly ground dove chicks in the first of two nests discovered at Nabu.



The female orange dove on her nest.

Orange dove nest

A nest of this species was found, with the female seen incubating a single white egg on a flimsy bare platform of twigs about 4m off the ground in a Makita tree. This nest was in the same area as the Natewa silktaill nests found in 2018, adding to the idea that the habitat in that area is optimal for some of the key endemic species on the peninsula. Unfortunately, the nest was found to be inactive after a week or so with the egg no longer in the nest, likely predated.

White-faced heron

There are currently no published records of the White-faced heron (*Egretta novaehollandiae*) on Vanua Levu at all, however we have made multiple records of it around the Savusavu area where it seems fairly common. It was most regularly seen on the airfield but has been seen on the coast and in wet pasture. Individuals were seen in multiple areas of the Natewa peninsula itself rather than just around Savusavu and three records were made from Taveuni. Records are being compiled and a paper being put together.

Natewa silktaill nesting

In 2018, we found and made observations of four active nests of the Natewa silktaill. There had only been one nest described from the Natewa peninsula before and so much of the information we found was new to science, see England (2019).

Future Recommendations

The last three years have been vital in establishing a solid methodology that we can take forward and use in future years, in order to maintain a long-term dataset. Whilst much of the time has been dedicated to doing this and carrying out the set surveys, many of the most important findings have been chance encounters. Now that methodologies and transects have been set, more effort can be made to explore and monitor currently un-surveyed parts of the peninsula. This effort should be focused particularly around high elevations where forest is least disturbed and along the periphery of the known Natewa silktaill distribution. This would allow us to better understand the natural primary habitat of the peninsula, whilst also finding the limits for the Natewa silktaill both geographically and ecologically. The same is the case for the yellow-billed honeyeater (which we need to prove exists on the peninsula) and any other species previously thought to be absent. Unfortunately, the Operation Wallacea season only runs for two months of the year and to get a true picture of what is going on in an ecosystem it needs to be monitored year-round, however this problem is difficult to overcome.

Particular attention should be given to maximising the number of recaptures of all species and especially captures of Natewa silktaill, ringing and measuring as many as possible to get more reliable data on their morphometrics and ecology. Should more nests be found, priority should be given to the observation of these. Small behavioural studies could be setup to quantify feeding, intra and interspecific interactions. The forest structure and carbon data collected in 2018 and 2019, once analysed will shed more light on the habitats present on the peninsula and will also allow us to identify correlations between species, their habitat and tolerance to disturbance. Given the peninsulas high endemism, a top priority should be to find

out what the underlying cause for such specialisation is. Undoubtedly this is partly due to the near island situation of Natewa, but will also be due to localised weather, geography, topography and the way these manifest themselves at the basic vegetation level.

A better understanding of the impacts of invasive species on the peninsula is needed, in particular the effects of the small Indian mongoose (*Herpestes auropunctatus*) on the avian community. Dietary analysis and experiments to determine the species' climbing ability are necessary to truly know whether it is having a negative impact on not just ground-nesting but cavity or tree-nesting birds as well.

Finally, it would be beneficial from a conservation standpoint to spend more efforts engaging and educating local communities about the importance of their forest. Formal training to interested parties in surveying, guiding, first aid and navigation could be given, which in turn would allow tourists and visitors outside the Operation Wallacea season to contribute to the local economy. Basic equipment could also be provided, through some sort of donation or funding. These ideas are already in the pipeline, but I do feel this is vitally important to the ongoing success of the project. The communities who own the land need to see not only biological worth, but economical worth in protecting their forests.

Arachnid Report

By Filippo Castellucci and Jane Hardwick

Introduction

Spiders represent a megadiverse group of animals, with more than 48,000 described species distributed in 120 families (World Spider Catalog “WSC” 2020). They are present in almost all terrestrial ecosystems (Foelix 2011), where they hold the role of key predators among the invertebrate communities (Nyfferler and Birkhofer 2017), and this makes them an interesting target taxon for trying to understand the biodiversity of a chosen area. Despite their ubiquity and abundance, they remain strongly understudied due to a lack of specialists focusing on their taxonomy, ecology, ethology or evolution, and for this reason arachnological surveys in tropical ecosystems are likely to lead to interesting findings.

To date, no arachnological survey was ever conducted in the Natewa Pensinsula and in general little research has been carried out at all in Fiji regarding this group of animals. The WSC (2020) currently reports only 92 spider species as present in Fiji, while a summary checklist produced by the Bishop Museum (Evenhuis and Bickel 2005) reports 130 species. Both checklists are likely to represent an underestimation of the real spider diversity, given the little effort and the ecological and biogeographical features of Fiji.

During 7 weeks of the 2019 Opwall expedition, the arachnological surveys were designed to estimate the sub-canopy diversity of spiders and of other minor orders of arachnids using a subset of collecting methods in order to access different microhabitats keeping the sampling protocol easy and applicable on the field by non-experts.

Methods

The arachnological surveys were carried out on the same transects that were also used for bird surveys and where habitat and carbon surveys were carried out (Figure 2). Arachnids were collected during a 10 minutes search session at each of the six transect points (in an area of approximately 20m surrounding the centre point). Ten of the 15 transects were surveyed twice and the remaining five just once due to time constraints and difficulties with access. The collecting team was led by either an experienced arachnologist (FC) or entomologist (JH) and assisted by trained local guides and 5-8 students who were trained on the day in invertebrate sampling. Prior to each survey a briefing was held by the team leader to explain and demonstrate the sampling techniques.

The methods chosen for collecting arachnids included active-search methods techniques at all sites including the use of three entomological sweep-nets, one vegetation beating tray and the use of active collection of specimens from spider webs or cryptic habitats as leaf litter or underneath logs/rocks. All the specimens collected at each point on a transect were pooled into one vial containing 70% ethanol and labelled with date, transect name and number of the transect point. Most survey plots were surveyed twice during the season.

After collection, the vials were sorted at the camp and the specimens contained in each vial were counted and identified to the lowest possible taxonomic category. Given the difficulty of identifying arachnids in the field without the use of a stereo-microscope, identification to the family level was recorded in most cases for spiders and to the order level for other arachnids.

In cases of striking and well visible morphological features, the specimens were identified up to the species level by FC.

Statistical analysis

After testing data for normality, analysis of variance (ANOVA) was carried out to assess if there were any differences in arachnid abundance and family richness across sites grouped into three habitat types (undisturbed forest, disturbed forest and road). Differences in community composition were assessed by calculating Jaccard's (based on presence/absence of arachnid families) and the Bray-Curtis (based on abundance of each arachnid family) indices for each site, and examining these on a betadisper plot which shows these data points embedded in a principle coordinates-derived Euclidean space. The three habitat types were grouped using convex hulls. Differences in habitats (based on each points distance to the centroid) were tested using ANOVA.

Results

Overview of specimens collected

In total, across the fifteen transects a total of 150 plots were surveyed (including repeated surveys) for arachnids. Almost 3000 arachnid specimens were collected across the peninsula in total. They included representatives from six different orders: Acarina (mites and ticks), Araneae (spiders), Opiliones (harvestmen), Pseudoscorpiones (pseudoscorpions), Schizomida (short-tailed whip-scorpions) and Scorpiones (scorpions). Opiliones, Pseudoscorpiones and Schizomida are of particular interest due to very little being known about their diversity even in well studied tropical forest locations. Among the scorpions, only one species was collected, belonging to the genus *Liocheles*, likely to be the species *L. australasiae*, which is widely distributed in tropical Asia, Australia and South Pacific.

Among the spiders, 15 different families were collected: Araneidae, Cheiracanthiidae, Clubionidae, Linyphiidae, Lycosidae, Mimetidae, Nesticidae, Pisauridae, Pholcidae, Salticidae, Sparassidae, Tetragnathidae, Theridiidae, Thomisidae and Uloboridae.

The total number of species collected is unconfirmed without formal taxonomic identification but could range between 60 and 80.

Spider abundance, family richness and community composition

There were seven survey plots where a mean of 40 or more arachnids were collected within the 10 minute search window. These were the most abundant plots and included three plots from C transect (C4, C5 and C6), three from Natovotovo transect (NAT3, NAT4 and NAT5) and one from Nabu (N5). These sites did not coincide with plots with the greatest family richness, which included two sites in KNMM (KA2 and KA5), one site in KNMM2 (KB5), two sites in A (A4 and A5) and one site in E (E1). All of these had a mean of more than six different families of arachnids identified. From the most family rich sites, all except one (E1) were undisturbed forest, whereas the most abundant sites for arachnids encompassed all three habitat types (undisturbed forest, disturbed forest and road habitat).

Although there was no difference in arachnid abundance across the three habitat types (undisturbed forest, disturbed forest and road) ($F = 0.399$, $df = 2$, $p = 0.67$), arachnid family richness was found to differ significantly across the three different habitat types ($F = 12.31$, df

= 2, $p = <0.001$). A Tukey HD test revealed that family richness was significantly greater in undisturbed forest sites when compared to that of disturbed forest sites ($p \text{ adj} = <0.01$) and road sites ($p \text{ adj} = <0.01$). There was no difference between arachnid family richness in road and disturbed forest sites ($p \text{ adj} = 0.72$) (Figure 10).

Overall community composition (based on beta diversity) was not different across the three different habitat types (Jaccard's index - $F = 0.595$, $df = 2$, $p = 0.55$, Bray-Curtis - $F = 0.657$, $df = 2$, $p = 0.52$). However, it is likely that species composition is altered with habitat change but further work (arachnid export and identification) is required to test this.

We found that 93% of Pseudoscorpionidae, 75% of Thomisidae were collected in undisturbed forest sites, 100% of Opiliones were collected in disturbed forests and Lycosidae and Pisauridae were only collected along road habitats.

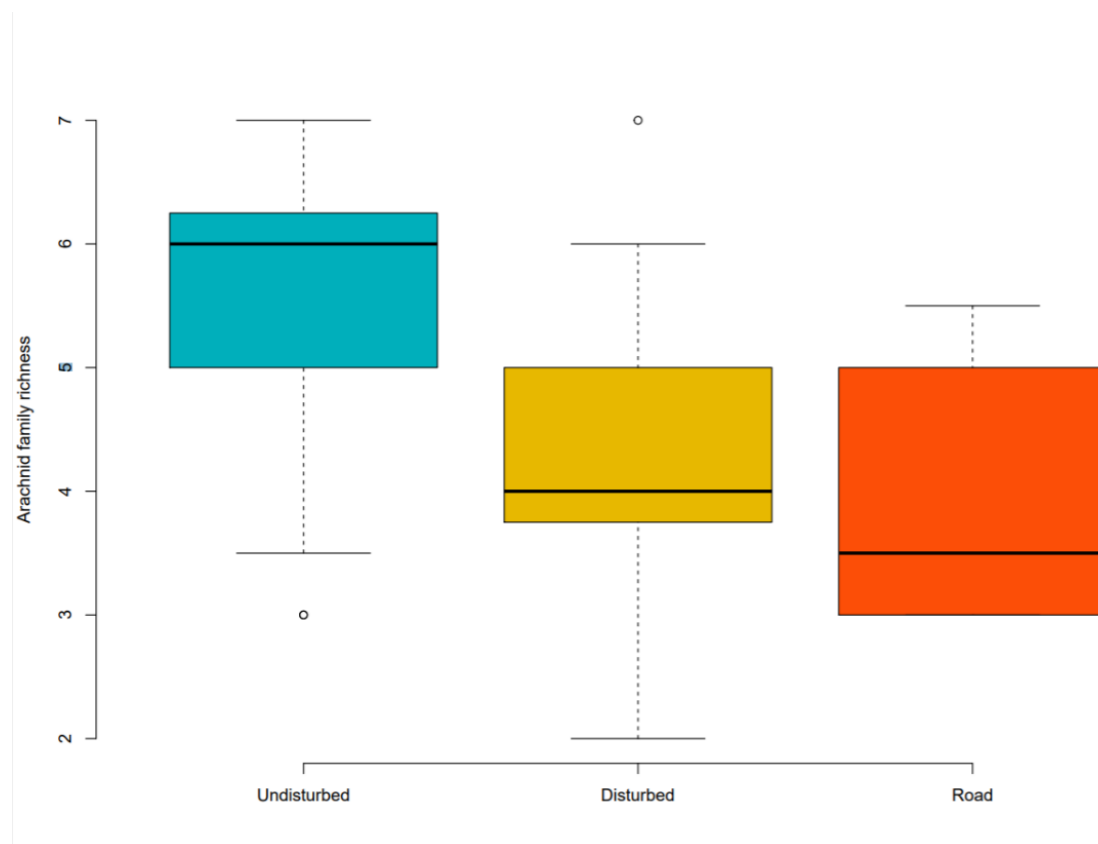


Figure 10. Arachnid richness (to family level) across three habitat types.

Further interesting findings

Araneidae (orb-weavers)

Several specimens of the big orb-weaver *Argiope pentagona* were collected on the forest transects. This species is endemic to Fiji. Many specimens belonging to the genus *Neoscona* were collected, representing at least 3 different species. Previous records indicate that four *Neoscona* species are recorded from Fiji, among which 1 is endemic (*N.*

flavopunctata). There is a good chance that this endemic species is present in the collected samples.

Clubionidae (sac spiders)

This family is not recorded for Fiji according to the WSC (2020), while an unidentified species of *Clubiona* from Fiji is present in the Bishop Museum collection (Evenhus and Bickel 2005). Some specimens were collected during our surveys and could represent new records for Fiji.

Lycosidae (wolf spiders)

The WSC (2020) reports only one species for Fiji, *Allocosa hostilis*, while the Bishop Museum (Evenhus and Bickel 2005) has two more unidentified species in collection. At least two different species were collected, among which there could be a potential new record for Fiji.

Pholcidae (daddy long-legs)

Several species were collected, including the Fiji endemic *Belisana fiji*.

Salticidae (jumping spiders)

Many species were collected. This family includes several Fiji endemic species, further taxonomical identifications of the specimens could reveal the presence of some of this endemic taxa in the collected samples.

Sparassidae (huntsman spiders)

Three species are recorded from Fiji. A big huntsman species that was common in the forest and around the forest camp seems to belong to the genus *Heteropoda*, but is totally different from *H. venatoria*, the only *Heteropoda* species recorded from Fiji and present in Vusaratu and at the marine site. This represents a new record for Fiji and further taxonomical analyses are needed to verify if this is a species already known to science.

Tetragnathidae (long-jawed orb-weavers)

Most of the common long-jawed orb-weavers collected in the forest belong to the genus *Leucauge*. No species is reported from Fiji according to the WSC (2020) and only *L. granulata* is present in the Bishop Museum collection (Evenhus and Bickel 2005). We collected at least two different species, so this is a potential new record for Fiji.

Theridiidae (cob-web spiders)

Three specimens belonging to the genus *Romphaea* were collected. This genus is not recorded from Fiji, so this represents a new genus record for the country.

Four different species of the klepto-parasitic spiders belonging to the genus *Argyrodes* were collected. Only two species are known to occur in Fiji, both endemic, so at least two endemic taxa were collected and at least two new species are recorded for the country.

Thomisidae (crab spiders)

Two endemic species are reported from Fiji, *Xysticus ictericus* and *Stephanopis erinacea*. Two species of *Xysticus* were collected, so this represent another Fiji endemic recorded for the Peninsula and a new record for Fiji. Several specimens belonging to the genus *Diaea*

were also collected. This genus is not recorded from Fiji, so this represents a new genus record for the country.

Discussion and Future Recommendations

There is no doubt that the arachnid diversity across the Natewa Peninsula is understudied and the results from the 2019 Opwall season are a strong indicator that further work must be continued on this group of invertebrates, with many new records recorded.

Previous studies worldwide have shown that arachnids are sensitive to habitat change (e.g. Bell *et al.* 2001; Pinkus-Rendon *et al.* 2006; Lo-Man-Hung *et al.* 2008). Our data shows that although abundance did not change, family richness of spiders was greatest in undisturbed habitats. This suggests that certain families of spiders may not survive habitat disturbances – for example we only collected one species from the Linyphiidae family in undisturbed forest and 93% of pseudoscorpionidae and 75% of Thomisidae species were collected in undisturbed habitats. However, certain arachnid families can thrive in disturbed habitats, for example Lycosidae and Pisauridae were only collected along road habitats, showing a preference for more open, grassy habitats.

As listed in the results, there are many interesting specimens that were collected over the survey period and it is likely that the percentage of interesting specimens will increase when the samples will be further analyzed using correct tools for a proper taxonomical identification. For example, some of the new records for Fiji could also represent species new to science.

Although a reduced set of sampling methods was applied, and species-rich habitats as the canopy or the leaf litter were not investigated, the results obtained are promising and clearly show how great the arachnological diversity is in the Natewa Peninsula and how little we know about the arachnofauna of Fiji.

In future seasons it would be useful to integrate different search techniques for enlarging the range of habitats covered by the surveys. Leaf-litter communities are commonly species-rich and can be accessed by the use of litter extraction techniques as Berlese funnels or positioning pitfall traps. The problem with these passive methods is that they are not suited for application by student groups.

Lepidoptera Report

By Clive Huggins (SBBT) and Visheshni Chandra (USP)

Introduction

Fiji has a number of endemic butterfly species and sub-species, one of which was only recently discovered in 2018 by OpWall teams, the Natewa swallowtail (*Papilio Natewa*). *P. Natewa* is one of only three known swallowtail species known to the Pacific (one other is a Fijian endemic *Papilio schmeltzi* and another in Samoa). Current knowledge suggests that *P. natewa* could be entirely restricted to the Natewa Peninsula, making it the one of the most range restricted Papilionidae species in the world (SBBT 2020). It is important to monitor the two endemic swallowtail species in Fiji as a previous study has found *P. schmeltzi* has a restricted range, occurs in low densities and are known to be impacted by forest loss (Chandra *et al.* 2013).

Records indicate that 46 species of butterfly occur in Fiji (prior to the discovery of *P. natewa*) (Tennent 2006; Patrick and Patrick 2012). In 2017 and 2018, Operation Wallacea teams carried out butterfly surveys in Vanua Levu, which were likely some of the first in recent decades and recorded a total of 14 species on the Natewa Peninsula. In 2019, further surveys on the Natewa Peninsula's butterfly fauna were required to provide a more complete picture of the population sizes and distributions. In particular, to follow up on the discovery of *P. natewa* with more in depth research on its' biology. At the current time the species had only been recorded within a few kilometers from the forest camp.

The overarching aim of the 2019 surveys were to conduct surveys across a variety of habitats on the Peninsula and to make a representative specimen collection for the Natural History Museum, London and University of the South Pacific, Suva. These records will supplement data collection from the previous two Opwall seasons by entomologists. In addition to Lepidoptera certain moths plus other insect Orders i.e. Longhorn (Cerambycidae) & Jewel (Buprestidae) beetles were assessed.

More specific aims of the season included:

1. Catch, identify and release butterflies across different survey locations in the Natewa Peninsula in an attempt to increase the species records from the previous years' work
2. Locate and collect a representative sample of *P. natewa* for museum specimens at University of the South Pacific and the London Natural History Museum
3. Record behaviours of *P. natewa* and carry out a mark and release surveys to determine the extent of their territories and flight paths
4. Confirm the larval food-plant for *P. natewa* and collect for herbarium identification at University of the South Pacific
5. Carry out mark and release surveys on common *Euploea* and *Hypolimnas* species which were easily identifiable by students to teach them the methods

These surveys will assist proving the Peninsulas' forests importance for endemic invertebrate species, in combination with other animals and plants being of sufficient unique value for it to be protected as a National Park.

Methods

Butterflies were collected using butterfly nets whilst walking along transects of varying distances. Five days a week, a group of students were taken on collecting trips, they were supplied with nets, for an introduction to various methods of entomological collecting and field work. A range of insect collecting methods were demonstrated so students could then have experience collecting different insect Orders, to inspire some to take up entomology, and make some contribution to the seasons recording. Local guides assisted with surveys and cut trails where necessary, to reach locations where no scientist had ever surveyed. The student groups were advantageous because often only one individual would catch a glimpse of a butterfly in flight that would require capture to determine its identity. For transect locations, which differed slightly to the other biodiversity surveys, see Figure 11.

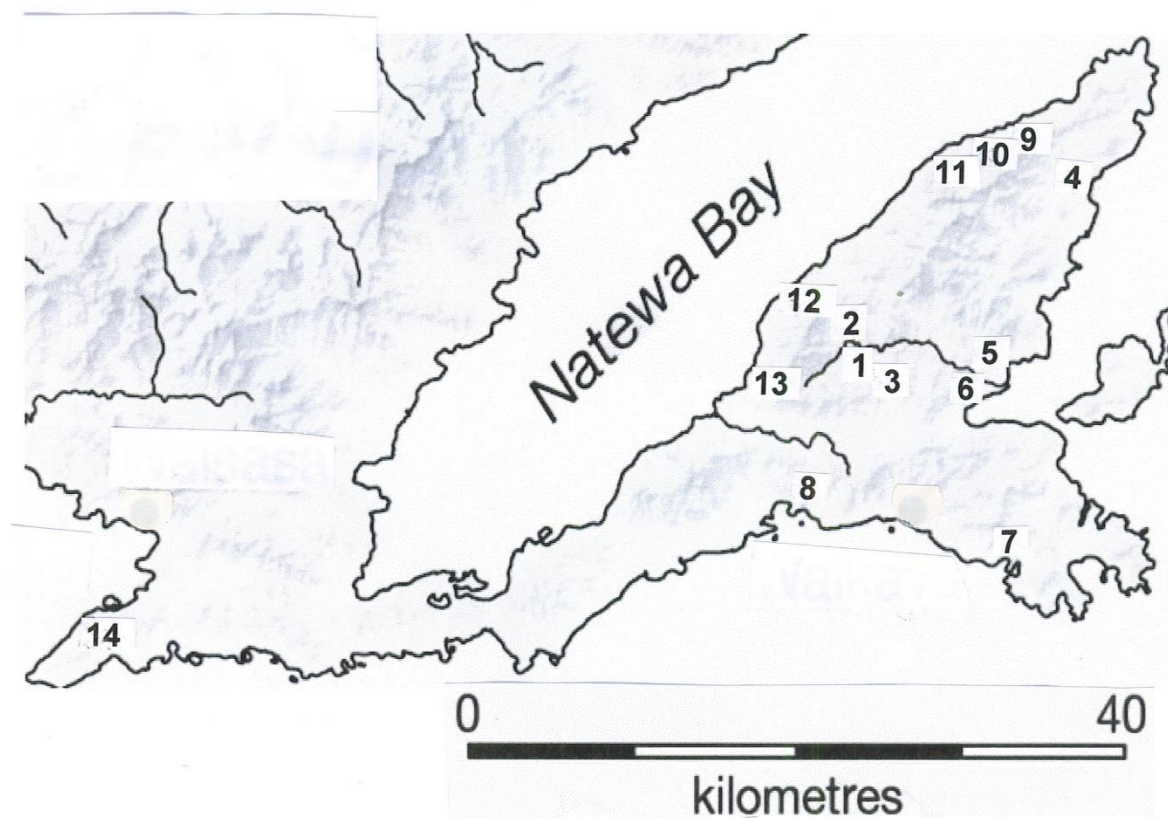


Figure 11. Butterfly survey locations (numbered) across the Natewa Peninsula (fia.umd.edu).

Localities where collecting or recording undertaken, corresponding to numbering on Figure 11.

- 1/ Forest Camp, 16.38'1079"S 179.45'2709"E. Elev.233m
- 2/ Forest Camp, track to Ridge (top of ridge track 380m)
- 3/ Forest Camp, track SE
- 4/ Natovotovo
- 5/ Tukavesi
- 6/ Mbutha
- 7/ Dakuniba
- 8/ Bagasau
- 9/ Navetau
- 10/ Wailevu
- 11/ Moana
- 12/ Vusaratu
- 13/ Nabu – (Marine camp).
- 14/ Savusavu – (chocolate plantation, outside peninsula)

Nb. Areas underlined in the list were additionally sampled by VC and the rest were surveyed by CH.

Results

The beginning of the season in June was extremely rainy (including two days of the heaviest rain that Opwall had experienced since beginning the research in Fiji) and this hindered surveys and sightings. *P. natewa* was captured in June but sightings were very few. The weather gradually improved and in early July sightings of *P. natewa* became more regular, along with other butterflies. A representative sample of *P. natewa* were located and collected (6 specimens retained), intentionally kept to a small number that would be unlikely to have a detrimental impact on the population. From 3rd July, the mark and release surveys commenced. Occasionally with the aid of radio communications between two teams to check on the flight path was attempted but deemed unsuccessful due to adverse weather or time restraints. Eventually, with patience, *P. natewa* was sighted almost daily on the ridge track. CH was able to locate and collect samples of suspected *P. natewa* larval foodplant which was a medium sized tree with fruit, these were sent to the herbarium at Fiji University for examination and identification.

Behavioural observations determined that *P. natewa* keeps to distinctly forest habitat, flying directly into or out of dense forest in search of food or courtship. Adults were only seen feeding on nectar of introduced flowering plant *Stachytarpheta* sp. The first ever sighting of male and female courtship flight was observed. An interesting observation was that *P. natewa* was only recorded within 2km of the camp and not in any other locations across the peninsula. A key habitat for the *P. natewa* was identified in 2018, which CH and VC returned to in 2019 to find the track had been bulldozed and all vegetation cleared by farmers, including any *Stachytarpheta* flowers. Due to this habitat change the transect was completely ruined for butterflies. However, a more promising finding was that Maika, the local butterfly guide, confirmed that *P. natewa* had continuous generations year-round, with population appearing to increase in July and August after the rainy season. Research on population size is ongoing.

The other Fijian endemic swallowtail species *P. schmeltzi* was also recorded by CH to occur in the same locality as *P. natewa*, feeding at the same location on the same flowers. However, it was not restricted to the transects close to camp and was sighted on multiple occasions at most survey locations (Table 3) around forests and usually near to a river.

From CH's surveys, the specimen collection comprised a total of 230 butterflies from the Natewa Peninsula from a conservative and provisional total of 21 butterfly species. These were mostly identified while in envelopes, however it is likely there will be a few additional species confirmed once they are set and can be properly examined and compared with a major collection such as the NHM, London. VC collected additional species, bringing the total number of species collected in 2019 to 25 out of the currently considered 47 in Fiji (Supp. Mat. Table S3). Four transects that were particularly species rich include Wailevu (14 species recorded), Natovotovo (13 species were recorded), the forest camp ride track (12 species recorded) and Tukavesi (11 species recorded). Of the *Euploea* and *Hypolimnas*, 157 and 93 individuals were recorded, respectively, and some 'marked' numbered individuals were subsequently recorded.

It was obvious by July more of all butterfly species were then emerging though butterfly sightings were usually scattered and rarely seen in profusion as might be expected in a tropical forest region. Around the Forest Camp butterflies were usually sparse and disappointingly few if overcast or afternoons then a challenge to record anything. There were few clear sunny days, on the majority it was partly cloudy with occasional showers. When too dull and wet for butterflies to be on the wing, students were kept occupied with talks on butterflies, insect curation and general entomology. On cloudy showery evenings there were large numbers of moths in evidence.

Table 3. List of all butterfly species recorded in 2019 on the Natewa Peninsula. *Refer to Figure 11 for numbered locality. List does not include 230 specimens collected by CH.

LOCALITY *		1	2	3	4	5	6	7	8	9	10	11	12	13	14		Tot
Hesperiidae - Family																	
<i>Badamia exclamationis</i>	CH				2												2
<i>Badamia atrox subflava</i>	VC		1														1
<i>Oriens augustula augustula</i>	CH	1	4		5	17		2	1			2					32
Papilionidae - Family																	
<i>Papilio schmeltzi</i>	CH				1						2				C		4
<i>Papilio natewa</i>	CH	4	3														7
Pieridae - Family																	
<i>Catopsilia pomona</i>	CH				1						1						2
<i>Catopsilia scylla gorgophone</i>	CH											?					1
<i>Eurema hecabe sulphurata</i>	CH		3	1	2	5	C	2			1	4	9				28
Lycaenidae - Family																	
<i>Strymon bazochii</i>	VC			1													1
<i>Nacaduba dyopa dyopa</i>	VC			1		1											2
<i>Jamides candrena</i>	CH	27	47	15	5			4	8		3	40	2				151
<i>Zizina labradus mangoensis</i>	VC							2	1		2						5
<i>Zizula hylax dampierensis</i>	CH									C							1
Nymphalidae - Family																	
<i>Tirumala hamata neptunia</i>	CH					1					?						2
<i>Danaus plexippus plexippus</i>	CH		1								2	1					4
<i>Euploea tulliolus forsteri</i>	CH				7	2					2	1		2			14
<i>Euploea boisduvalii boisduvalii</i>	CH	8	9	13	8	31			5		4			2			80
<i>Euploea lewinii eschscholtzii</i>	CH	2	16	3	4	24			5		3	2		4			63
<i>Melanitis leda solandra</i>	CH	1		1		1									C		4
<i>Xois fulvida</i>	CH	9	15		1	18			4						C		48
<i>Polyura caphontis caphontis</i>	CH				1								1				2
<i>Hypolimnas antilope lutescens</i>	CH		1								2	2					5
<i>Hypolimnas bolina pallelescens</i>	CH	1	17	5	15	6		8	20		5	4	3	4			88
<i>Junonia villida villida</i>	CH		2	2	1	4	C	3	6		1	1	2				23
<i>Vagrans egista vitiensis</i>	CH								2		C						3
No. of Species		8	12	9	13	11	2	6	9	1	14	10	5	4	3		
Total recorded																	573

Discussion and Future Recommendations

Both endemic Swallowtail species are very much dependant on a forest habitat as would be the case for certain other butterfly species. This highlights the need for protection of the remaining forests across the peninsula, as these habitats are being converted to farms across most of the lowland areas. Furthermore, more local awareness is recommended. Using findings from Opwall's research season, areas of particular importance could be mapped and discussed with local landowners. Further surveys are required to determine the distribution of *P. natewa* as for the second year running it has only been located on transects close to camp, and one possible record in Nabu, despite many surveys being carried out further afield. If possible, year-round surveys may determine more information about the species. This finding indicates again that the habitat requirements are specialised, expressing the great need for habitat protection. Further work on the *Euploea* species would also be beneficial as they show considerable wing pattern variation and mimicry (Deshmukh *et al.* 2018). DNA analysis may be required to determine the true taxonomic relationships and there may be undescribed taxa involved.

Local communities and VC are interested in setting up a *P. natewa* breeding facility to help boost population numbers on the peninsula. However, funding is required for this which could be a limitation. If successful and populations are increased, this could later increase eco-tourism for butterfly/wildlife enthusiasts who wish to see species that cannot be seen anywhere else in the world.

As few butterflies were to be found around the forest camp in the afternoons, time could be better spent seeking other insect groups with use of sweep nets, beating tray and pitfall traps. In the forest trails there were only two or three species that might be seen and it was only in clearings that more butterflies might be found.

To identify key *P. natewa* habitats, an additional vehicle would be required for Butterfly groups 2 - 3 days a week. More mornings are needed away from forest camp and surveying new localities around coast and into central forested hills. CH missed Dakuniba altogether and only made a recce visit to Tukavesi due to lack of transport. However, feedback was received on interesting behaviour missed at Dakuniba from other teams. Further surveys should be continued at Tukavesi after an area with abundant interesting butterflies was observed. An extension of the survey locations should include the area in the narrow southwest end of the Peninsula as there have been species observed in Savusavu at the chocolate plantation that were not found at our surveyed sites.

If drying fresh specimens, photograph sample of each species (including underside of folded wings) and then place in killing jar in envelopes. Leave on the dashboard of a hot car in sun for a few hours to dry.

Next season butterfly transects should be properly recorded with GPS location (this season there were not enough GPS devices for each team to have one). It would also assist if they are marked and labelled at the start, perhaps on a tree. Finally, a topographical map of Natewa and a vegetation map, would assist in searching out forest areas and locating suitable habitat (an example shown in Supp. Mat. Figure S2).

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Supplementary Material

Ring Number	2017	2018	2019	Date Ringed	Time Ringed	1st Recapture	2nd Recapture	Colour Rings	Age	Sex	CP	BP	Weight (g)	Head Bill (mm)	Wing (mm)	Tarsus (mm)	Tail (mm)	Tail Patch Length (mm)	
AP 16807	Y	Y	N	20/06/2017	16:45	15:30	29/06/2018		A	M	Y	N		13	30.5	71	17.5	46	NA
AP 16815	Y	N	N	27/06/2017	16:45				A	M	Y	N		11	31	69	19.5	41.5	NA
AP 16824	Y	Y	N	13/07/2017	16:40	16:40	02/08/2018		A	M	Y	N		12	32	69	17.5	41	45.5
AP 16826	Y	N	N	15/07/2017	16:40				J	U	N	N		12	31.5	69	17.5	43	NA
AP 16827	Y	Y	N	16/07/2017	16:40	15:50	27/07/2018		A	M	Y	N		12	34	70	17.5	45	NA
AP 16840	Y	N	Y	28/07/2017	16:45	16:30	31/07/2017	Pink/Green	A	M	Y	N		12	31.5	69	18	41	42
AP 16842	Y	N	N	28/07/2017	16:45				A	F	N	Y		NA	34.5	70	19	44	NA
AP 19714	N	Y	N	20/07/2018	15:20				A	U	N	N		12	30.5	70	19.5	42.5	NA
AP 19715	N	Y	N	20/07/2018	15:20				A	U	N	N		12	31	67.5	19.5	39.5	NA
AP 19718	N	Y	N	01/08/2018	15:32				A	F	N	Y		12	31.5	68.5	19	48.5	43
AP 19723	N	N	Y	26/06/2019	16:00			Light Blue/Pink	A	F	N	Y		10	31	68	19	35	44.5
AP 19725	N	N	Y	09/07/2019	16:50			Yellow/Green	A	U	N	N		12.5	31	73	20	38	45
AP 19726	N	N	Y	10/07/2019	16:40			Dark Blue/Red	J	U	N	N		10.5	30	70	18	34	37
AP 19727	N	N	Y	11/07/2019	16:15			Brown/White	J	U	N	N		12	31.5	71	19	40	41.5
AP 19728	N	N	Y	11/07/2019	16:15			White/ Dark Blue	A	M	Y	N		11	33	69	18	41	37

Table S1. A summary of all Natewa Silktaill captures in 2017, 2018 and 2019.

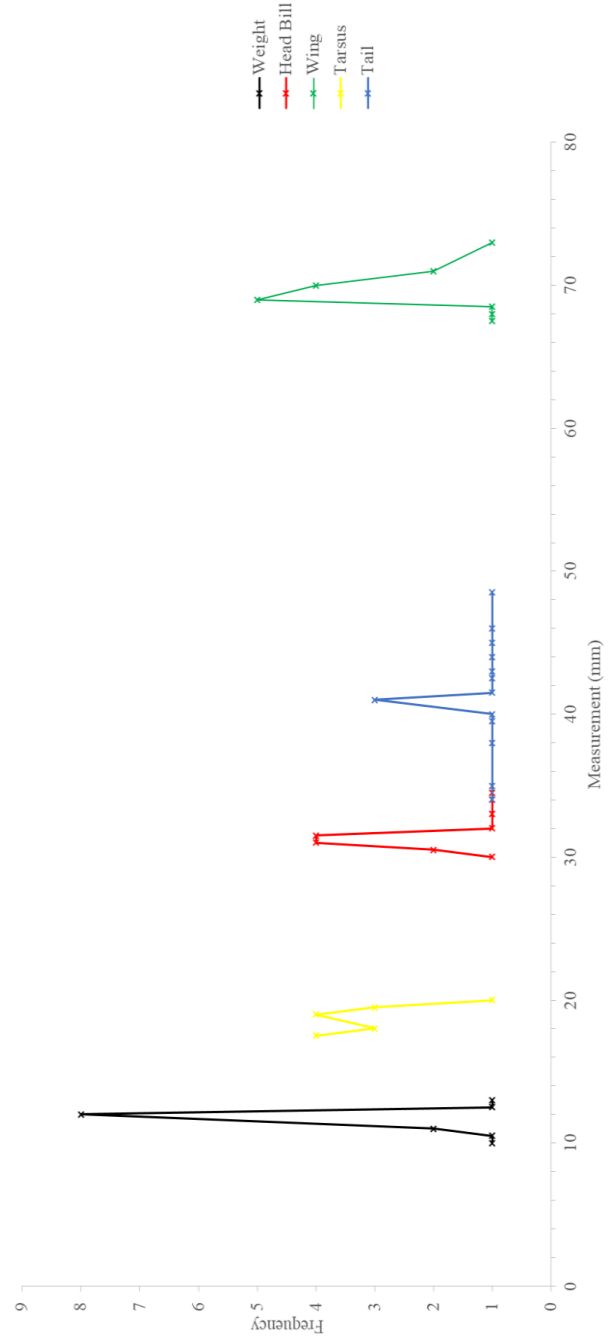


Figure S1. The frequency and distribution of different measurements from all Natewa silktaill caught in 2017, 2018 and 2019.

Table S2. Bird species recorded by Operation Wallacea on the Natewa peninsula in 2017, 2018 and 2019.

<u>Scientific Name</u>	<u>Common Name</u>	<u>Endemic</u>
<i>Sula sula</i>	Red-footed Booby	No
<i>Sula leucogaster</i>	Brown Booby	No
<i>Fregata ariel</i>	Lesser Frigatebird	No
<i>Butorides virescens</i>	Mangrove Heron	No
<i>Egretta novaehollandiae</i>	White-faced Heron	No
<i>Egretta sacra</i>	Eastern Reef Egret	No
<i>Anas superciliosa</i>	Pacific Black Duck	No
<i>Accipiter rufitorques</i>	Fiji Goshawk	Yes
<i>Circus approximans</i>	Swamp Harrier	No
<i>Falco peregrinus</i>	Peregrine Falcon	No
<i>Gallus gallus</i>	Red Junglefowl	No
<i>Pluvialis fulva</i>	Pacific Golden Plover	No
<i>Tringa incana</i>	Wandering Tattler	No
<i>Thalasseus bergii</i>	Great Crested Tern	No
<i>Sterna sumatrana</i>	Black-naped Tern	No
<i>Anous stolidus</i>	Brown Noddy	No
<i>Anous minutus</i>	Black Noddy	No
<i>Columba vitiensis</i>	Metallic Pigeon	No
<i>Spilopelia chinensis</i>	Spotted Dove	No
<i>Gallicolumba stairi</i>	Friendly Ground Dove	No
<i>Ducula latrans</i>	Barking Pigeon	Yes
<i>Ptilinopus perousii</i>	Many-coloured Fruit Dove	No
<i>Ptilinopus victor</i>	Orange Fruit Dove	Yes
<i>Phigys solitarius</i>	Collared Lory	Yes
<i>Prosopeia personata</i>	Maroon Shining Parrot	Yes
<i>Cacomantis flabelliformis</i>	Fan-tailed Cuckoo	No
<i>Tyto alba</i>	Barn Owl	No
<i>Aerodramus spodiopygius</i>	White-rumped Swiftlet	No

<i>Todiramphus chloris</i>	Collared Kingfisher	No
<i>Hirundo tahitica</i>	Pacific Swallow	No
<i>Lalage maculosa</i>	Polynesian Triller	No
<i>Pycnonotus cafer</i>	Red-vented Bulbul	No
<i>Turdus poliocephalus</i>	Island Thrush	No
<i>Horornis ruficapilla</i>	Fiji Bush Warbler	Yes
<i>Rhipidura verreauxi</i>	Streaked Fantail	Yes
<i>Lamprolia klinesmithi</i>	Natewa Silktail	Yes
<i>Mayrornis lessoni</i>	Slaty Monarch	Yes
<i>Clytorhynchus vitiensis</i>	Fiji Shrikebill	Yes
<i>Myiagra vanikorensis</i>	Vanikoro Flycatcher	No
<i>Petroica pusilla</i>	Pacific Robin	No
<i>Pachycephala vitiensis</i>	Fiji Whistler	Yes
<i>Zosterops explorator</i>	Fiji White-eye	Yes
<i>Zosterops lateralis</i>	Silvereye	No
<i>Myzomela jugularis</i>	Sulphur-breasted Myzomela	Yes
<i>Foulehaio taviunensis</i>	Fiji Wattled Honeyeater	Yes
<i>Gymnomyza viridis</i>	Yellow-billed Honeyeater	Yes
<i>Artamus mentalis</i>	Fiji Woodswallow	Yes
<i>Aplonis tabuensis</i>	Polynesian Starling	No
<i>Acridotheres tristis</i>	Common Myna	No
<i>Amandava amandava</i>	Red Avadavat	No
<i>Erythrura pealii</i>	Fiji Parrotfinch	Yes
Total	51	17

Table S3. Full butterflies of Fiji list with those recorded by Operation Wallacea in 2019 marked with either CH (Clive Huggins) or VC (Visheshni Chandra). 30% listed below are endemic to Fiji and 36% of species found in Natewa are Fiji endemics.

BUTTERFLIES OF FIJI			
SCIENTIFIC NAME		COMMON NAME	ENDEMIC
Hesperiidae - Family			
<i>Badamia exclamationis</i>	CH	Almond Skipper	
<i>Badamia atrox subflava</i>	VC	Pacific Awl	subsp
<i>Hasora chromus bilunata</i>		Common Banded Awl	
<i>Oriens augustula augustula</i>	CH	Fijian Skipper	subsp
Papilionidae - Family			
<i>Papilio schmelzti</i>	CH	Fijian Swallowtail	sp
<i>Papilio natewa</i>	CH	?	sp
Pieridae - Family			
<i>Catopsilia pomona</i>	CH	Lemon Migrant	
<i>Catopsilia pyranthe lactea</i>		White Migrant	
<i>Catopsilia scylla gorgophone</i>	CH	Yellow Migrant	
<i>Eurema hecabe sulphurata</i>	CH	Common Sulphur	
<i>Eurema brigitta australis</i>		Small Grass yellow	
<i>Appias athama athama</i>		Pacific Albatross	
<i>Appias paulina ega</i>		Yellow Albatross	
<i>Cepora perimale perithea</i>		Caper Gull	subsp
<i>Belenois java clarissa</i>		Capper White	subsp
Lycaenidae - Family			
<i>Deudorix epijarbas diovella</i>		Dull Cornelian	
<i>Strymon bazochii</i>	VC	Lantana Blue	
<i>Nacaduba dyopa dyopa</i>	VC	Owl-spotted Blue	
<i>Nacaduba biocellata armillata</i>		Acacia line-Blue	
<i>Jamides kava</i>		?	
<i>Jamides candrena</i>	CH	Fijian Blue	sp
<i>Catochrysops taitensis taitensis</i>		Silver Pea-blue	
<i>Lampides boeticus</i>		Long-tailed Blue	
<i>Famegana alsulus lulu</i>		Black-spotted Blue	
<i>Zizina labradus mangoensis</i>	VC	Common Blue	
<i>Zizula hylax dampierensis</i>	CH	Tiny Blue	
<i>Euchrysops cnejus samoa</i>		Pacific Spotted pea-blue	
Nymphalidae - Family			
<i>Tirumala hamata neptunia</i>	CH	Blue Tiger	
<i>Danaus petilia</i>		Australian Wanderer	
<i>Danaus plexippus plexippus</i>	CH	Monarch	
<i>Euploea leucostictos macleayi</i>		Fijian crow	subsp
<i>Euploea tulliolus forsteri</i>	CH	Purple Crow	
<i>Euploea boisduvalii boisduvalii</i>	CH	Pacific Crow	

<i>Euploea lewinii eschscholtzii</i>	CH	Common Crow	
<i>Melanitis leda solandra</i>	CH	Evening Brown	
<i>Xoïs fulvida</i>	CH	Bordered Fijian ringlet	sp
<i>Xoïs sesara</i>		Common Fijian ringlet	sp
<i>Polyura caphontis caphontis</i>	CH	Tailed Emperor	sp
<i>P. caphontis nambavatua</i>		"	subsp
<i>Doleschallia tongana vomana</i>		Pacific Orange leafwing	
<i>Hypolimnias antilope lutescens</i>	CH	Fijian Eggfly	sp
<i>Hypolimnias octocula octocula</i>		Pacific Eggfly	
<i>Hypolimnias bolina pallescens</i>	CH	Blue Moon	
<i>Hypolimnias inopinata</i>		Plain Eggfly	
<i>Junonia villida villida</i>	CH	Meadow Argus	
<i>Cynthia kershawi</i>		Australasian Painted Lady	
<i>Vagrans egista vitiensis</i>	CH	Tailed Rustic	subsp
<i>Acraea andromacha polynesiaca</i>		Glass Wing	
	47 Species		
Other records			
<i>Papilio godeffroyi</i>	a stray		
<i>Callophrys rubi</i>	one off introduction		
<i>Euploea treitschkei jessica</i>	not Fijian		

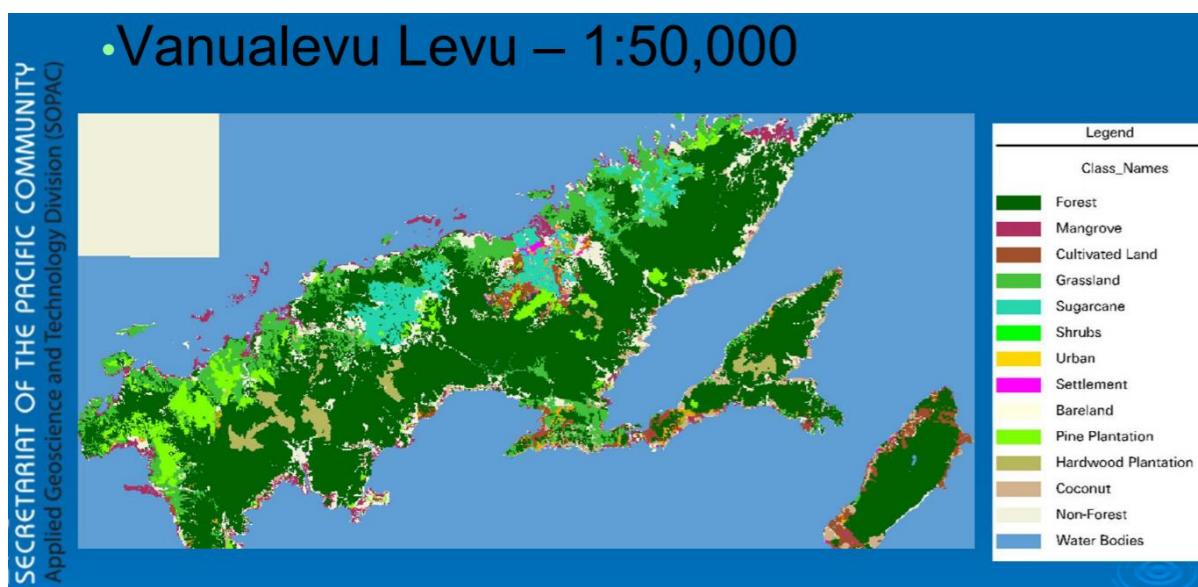


Figure S2. Broad vegetation map of Vanua Levu
(https://www.fig.net/resources/proceedings/2013/fiji/ppt/ts2b/ts2b_Qionitoga.pdf).