The Diversity of Butterflies at Iracambi

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ABSTRACT

The *Mata Atlântica* tropical forest is one of the most threatened biomes on the planet, with only around 13% of its original extent remaining in a fragmented state. The precise impact of this habitat loss on biodiversity is unclear. Iracambi is an NGO owning land in the state of Minas Gerais, south eastern Brazil, which consists of a mosaic of forest and farm land. Here, butterfly diversity was sampled using a range of methods. Novel species for the area were recorded, with photographic sampling being especially useful in increasing the diversity of butterflies that could be recorded. Trapping methodologies were explored and should be improved for future research. Strong habitat preferences were present in some species, suggesting a mosaic of land uses may be beneficial to butterfly diversity (as one aspect of the biodiversity of the region). Two possible tiger mimicry rings involving *Hypothyris*, *Mechanitis*, *Placidina* (and perhaps *Melinaea*) were identified in the lower strata (1–4m) of the forest.

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INTRODUCTION

The Atlantic Forest (*Mata Atlântica*) is a tropical forest ecosystem, stretching along the Atlantic coast of Brazil from the state of Rio Grande do Norte to Uruguay and Argentina in the south, encompassing a variety of habitats including dry forests, moist forests and mangroves (Mongabay 2012). The *Mata Atlântica* contains high levels of biodiversity and thus qualifies as one of the Earth's five hottest biodiversity hotspots (Myers et al. 2000). The region contains 2.7% of the world's endemic plants and 2.1% of its endemic vertebrates (Myers et al. 2000): these taxa are found nowhere else but the *Mata Atlântica*. The state of Minas Gerais (smaller than the state of Texas) contains more bird species (780) than the whole of the United States (Mattos et al. 1993, Le Breton 2000). One eighth of the entire global butterfly fauna, and two thirds of Brazil's, are represented in the 2124 species of butterfly in the region (Coleman 2004).

But the *Mata Atlântica* is no longer a continuous forest. It now exists in a desperately fragmented state (Figure 1). Before the Portuguese arrival in Brazil in the Sixteenth Century, the *Mata Atlântica* spread over a million square kilometres, but now only 13% of the original area remains in fragments over three hectares. Of this forest, 41% is in fragments of less than one hundred hectares (INPE 2012). Human activities, primarily coffee, sugarcane and eucalyptus agriculture and cattle farming have damaged, and continue to threaten, the forest ecosystem.

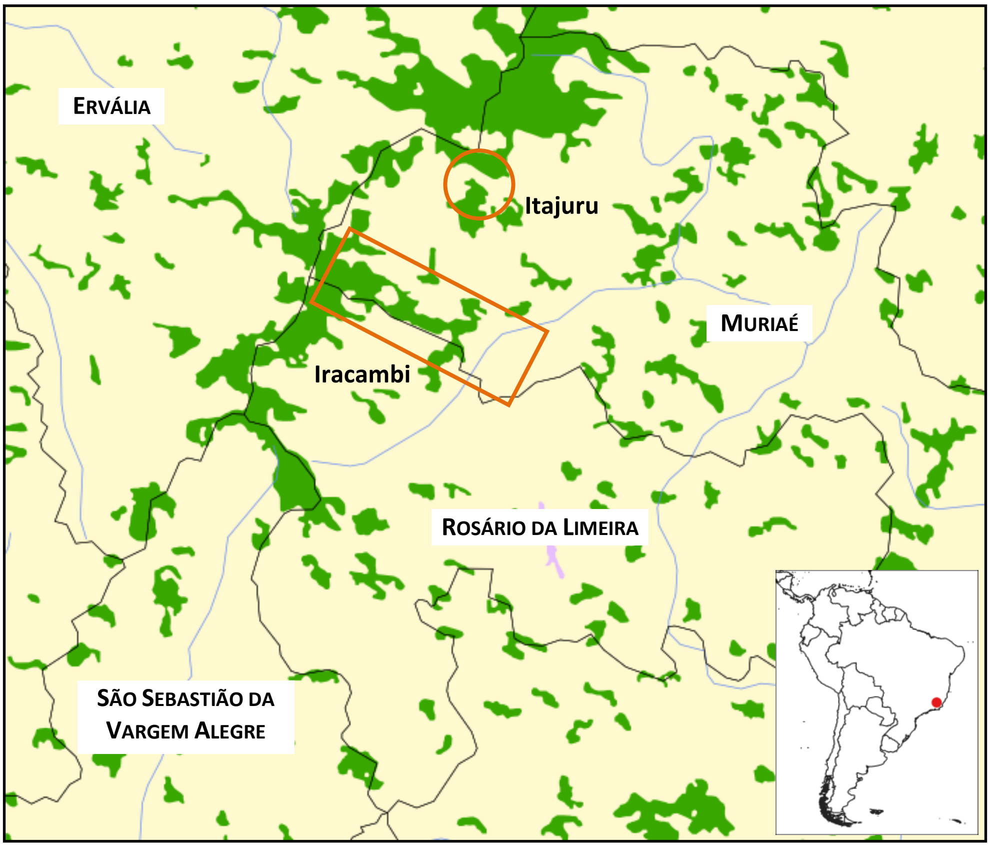

Figure 1 Remaining *Mata Atlântica* coverage in the study area. Yellow: open land. Green: forest. Orange box: approximate location of Iracambi, within the *município* of Muriaé. Orange circle: approximate location of Itajuru highland.

Deforestation and fragmentation are taking their toll on tropical forests, altering community composition and ecosystem function (e.g. Didham et al. 1998) and increasing extinction risk. According to the theory of island biogeography (MacArthur & Wilson 1967), habitat fragmentation will lead to a general loss of species richness and biodiversity within habitat fragments. Under particular threat are organisms that are forest specialists, are sparsely distributed or need large home ranges (Turner 1996).

The effect of habitat fragmentation on butterfly diversity is less straightforward. Some species and guilds seem to prefer open, disturbed habitats whilst others are forest specialists (Uehara-Prado & Freitas 2008). Consequently, regions incorporating fragmented forest can actually have surprisingly high gamma diversity (at the landscape scale), whilst the alpha diversity within individual fragments is low (Daily & Ehrlich 1994, Benedick et al. 2006).

Maintaining butterfly diversity is important because of the essential ecological role of butterflies. Adult butterflies are important pollinators of a variety of flowers, and both adults and juveniles (caterpillars) are a key food source for predatory birds. Butterflies are also good indicator species for overall biodiversity owing to their short generation time, ecological specialisation and, from a practical perspective, their conspicuousness (Brown & Freitas 2000).

This report aims to extend previous studies of the butterflies present across the Iracambi estate (Baliga & Buckley 2001, Coleman 2004, Ventress 2008). Iracambi is a small NGO, farm and research centre located in the north western corner of the *município* of Muriaé in the state of Minas Gerais, Brazil (Figure 1). Iracambi has an ethos of conservation through sustainable development. Conservation is especially pertinent in one of the most deforested states in the *Mata Atlântica* region, both in terms of percentage forest cover remaining and absolute forest loss. Before European settlement, Muriaé was completely covered in forest; now only 9% remains (INPE 2012, Mongabay 2012). Iracambi owns over five hundred hectares of land (Le Breton 2000) following the recent acquisition of land around Graminha, to the north of the original estate. The Iracambi estate consists of matrix of a variety of land uses including roads, grazing fields, forest fragments of various sizes, swamps, rivers and floodplains. The Iracambi estate is used for a combination of research, education, conservation and ecotourism.

The aims of this project are to:

- Augment the sampling effort applied to butterflies at Iracambi to increase species level taxonomic coverage;
- Provide further details about butterflies at Iracambi, specifically abundance, habitat preferences and georeferenced locations;
- Experiment with the use of new sampling methods (specifically traps baited with fermenting fruit);
- Compare butterfly diversity in the late winter of 2012 with diversity in other seasons and in other years. Long-term records like the one developing at Iracambi are rare but invaluable in ecology and conservation (Magurran et al. 2010), allowing the identification of trends and patterns that may otherwise be obscured by short-term idiosyncrasies.

METHODS

Between August 11th and September 4th 2012, butterflies were sampled across and around the Iracambi estate (Figures 2 & 3). Butterflies were chosen as an apparent and easily identifiable indicator species for biodiversity, for which previous studies were available for comparison.

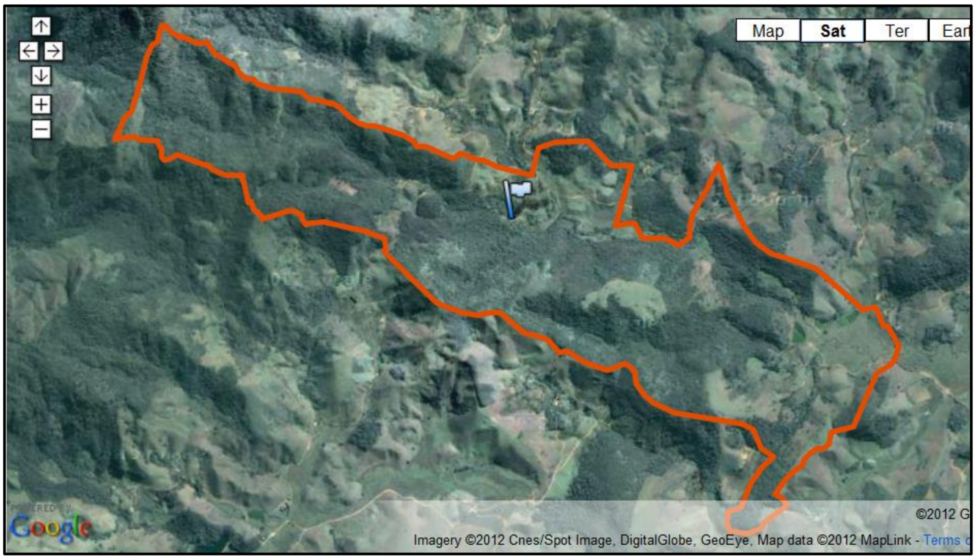

Figure 2 Location of the Iracambi estate (orange border). To explore the map yourself, visit http://en.iracambi.com/about-us/where-we-are [Accessed December 2012].

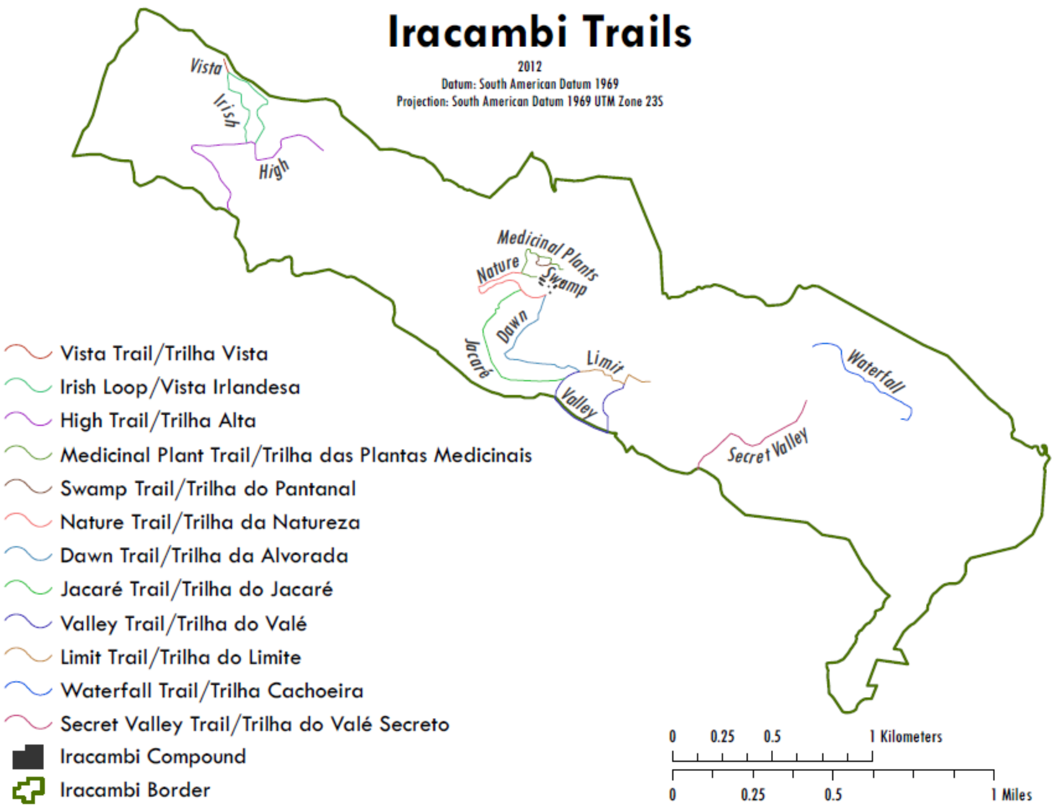

Figure 3 Location of trails across the Iracambi estate, used for access to and sampling in forested areas. Not all trails were accessible at time of sampling.

Sampling locations were selected to cover a wide range of environments at Iracambi. Sampling was largely conducted along roads, where butterflies were obvious and relatively easy seen or caught, and along the series of trails that are maintained through the forest across the estate These trails encounter a range of habitats. Additional sampling was carried out in sugar cane and coffee plantations, and on the mountains of Graminha and Itajuru, north of the Iracambi estate (Figures 1 & 7). Sampling effort was not applied equally across these locations: more sampling time and effort was applied to areas with greater apparent butterfly diversity (consistent with the aim of documenting as much diversity across Iracambi as possible, not necessarily comparing the diversity of different sites). Indeed, some of the most diverse trails were walked more than once, but this was always done with at least a week interval, in the opposite direction at a different time of day and, where possible, in different weather conditions to maximise the number of species encountered. Opportunistic samples were also taken whilst walking to and from designated sampling areas (primarily to increase the geographic coverage of presence records for each species).

In each of these locations, butterflies were caught on camera and where possible (in the majority of cases) using a hand net. This was constructed by the author at Iracambi, consisting of a bamboo handle and cross frame supporting a wire net (Figure 4a). Butterflies that were caught were transferred to a plastic freezer bag, subjected to preliminary identification in the field, and measurements were taken of body length (from the tip of the head, excluding antennae, to base of the abdomen) and wingspan (double the distance from the upper wing tip to the body; this was more comparable across individuals than measuring actual wingspan since spreading the wings of the butterflies whilst alive was not always easy or even possible). Photographic records were taken and the butterflies released alive and physically unharmed. Where butterflies were not caught but only photographed, size was estimated either by eye or, where possible, by immediately comparing the photograph with the resting place of the butterfly (for example, measuring the distance between veins on a leaf that marked the wingspan of the butterfly when it was resting on that leaf). Although these estimates are very crude, they demarcate records into rough small, medium and large size classes and thus aid in identification.

GPS coordinates for each location were recorded, signal permitting, using a Garmin Handheld GPS device. The number of satellites used to calculate each location was also recorded as an indicator of accuracy. A weak or absent signal precluded coordinates from being obtained for some locations, especially through trails with dense canopy cover: these locations were georeferenced later as accurately as possible using Google Maps.

Also in the laboratory, as soon as possible after fieldwork, the results from each day's sampling were entered into a spreadsheet and the photographs used to confirm species identities hypothesised in the field. The field guide of Ventress (2008) was used as the primary resource for identification.

Additional butterflies were sampled using a butterfly trap, also made by the author at Iracambi based on the methodology of Venters (2012). Dimensions and materials are given in Figure 4b. The trap was baited with fermented banana: mashed banana to which baker's yeast had been added and the whole mixture left for 1–3 days. Traps were set at 1.5–2m height for at least 24 hours, but were inspected regularly (at least twice a day) to identify and release any captured animals.

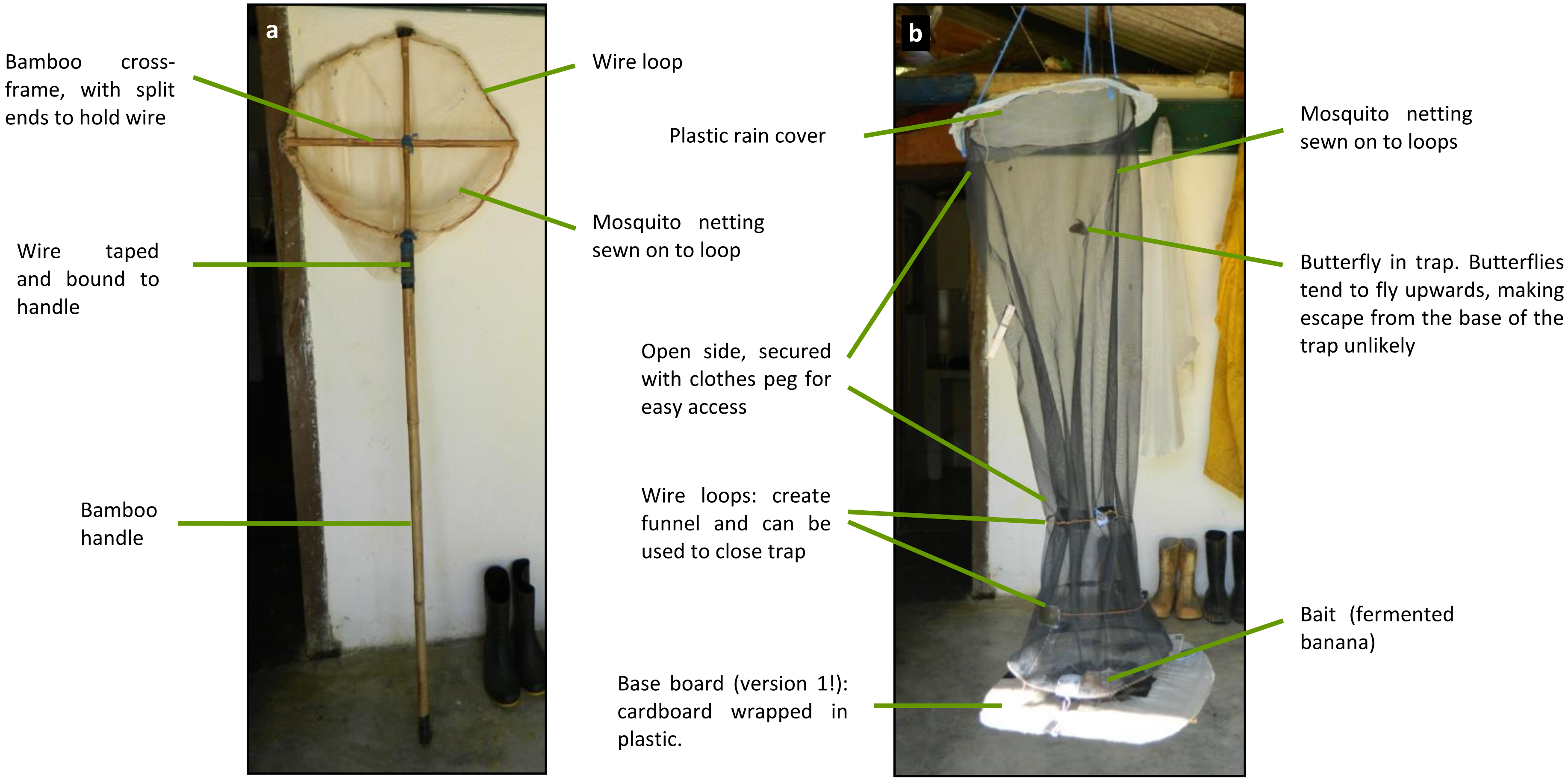

Figure 4 Sampling equipment. a) Hand net b) Butterfly trap. Equipment was left in Iracambi tool shed in September 2012, so will hopefully be available for future use! Approximate dimensions: Net height = 160cm, width = 50cm; Trap height = 80cm, large ring diameter = 23cm, small ring diameter = 8cm, base plate diameter = 26cm.

RESULTS

Trapping

Data obtained from trapping are considered separately because this part of the project tended towards an experiment in methodology rather than an accurate survey of diversity. Only nine individuals in five species were ever seen associated with traps (Table 1). *Caligo illioneus* was only observed feeding on the underside of the trap; it was not caught.

In addition to the locations listed in Table 1, unsuccessful traps were set on the Dawn Trail and Waterfall Trail, both for at least 24 hours.

Table 1 Butterfly species recorded in traps around Iracambi, 2012. R: number of records.

Species	R	Locations
Hermeuptychia hermes	3	Nursery
Cappronieria galesus	3	Nursery, Centro
Hamadryas epinome	1	Nursery
Archeuptychia cluena	1	Nature Trail
Caligo illioneus	1	Nursery

Observed butterfly diversity

In total, 364 individual butterflies were recorded. These were representatives of approximately 100 species in 66 genera, although it is impossible to give a precise number with uncertainties in species identification. These totals include individuals that could only be identified to a hypothesised generic or familial level. 82 distinct species could be identified with a reasonable level of confidence i.e. observed species richness (Σn) = 82. The species are listed in Appendix 1.

Some species were much more common than others. By far the most common species was *Hermeuptychia hermes* with 49 records (13.5% of the total 364 records). *H. hermes* was frequently observed in roadside vegetation and along more open, grassy forest paths but never in closed forest. Other common species were *Junonia evareta* (12 records, 3.3%), *Tegosa claudina* (10, 2.8%) and *Hypothyris ninonia daeta* (10, 2.8%). In contrast, 31 species (8.5%) were known from only a single record. The distribution of abundances of records for genera (and families) is shown in Figure 5. This rank abundance plot of genera is strongly skewed to the right (X^2 test compared to null expectation of all genera in equal proportions $p < 0.001$, $df = 65$).

Diversity indices can give a better representation of communities such as this (compared to simple species richness) because they incorporate relative abundance of species (as well as species richness). A community in which the abundances of species are similar is intuitively more diverse than a community dominated by one species, with a few individuals of other species. It may be helpful to consider diversity indices as a reflection of predictability in the community: the greater the diversity index, the less predictable the identity of the next species to be sampled from the community. Diversity indices for this study are presented in Table 2.

It is also useful to consider the relationship between species richness and sampling effort. The more time spent sampling (i.e. the greater the sampling effort), the greater the number of species observed, as rarer species are included in the total sample. This positive, non-linear

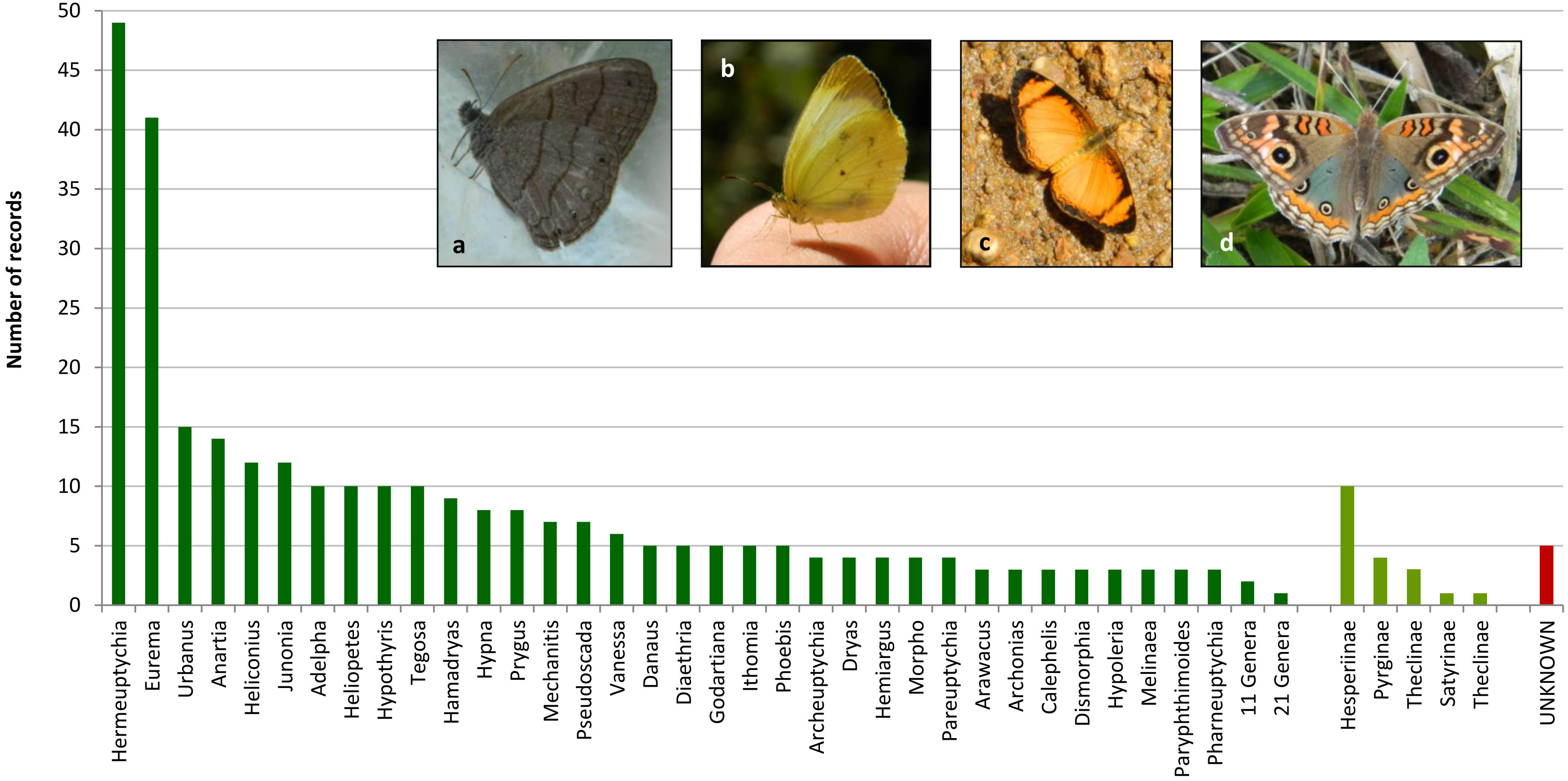

Figure 5 Number of individuals recorded in taxonomic groups. Dark green bars: genera. Note the dominance of *Hermeuptychia* (all *H. hermes*) and *Eurema* (mixed species). Light green bars: number of individuals in families not identified to genus level. Red bar: individuals that could not even be identified to family level.

Inset species examples a) *Hermeuptychia hermes* b) *Eurema albula* c) *Tegosa claudina* d) *Junonia evareta.*

relationship is illustrated in Figure 6, showing the cumulative number of species recorded in this study against the time spent sampling (measured as number of hours per day).

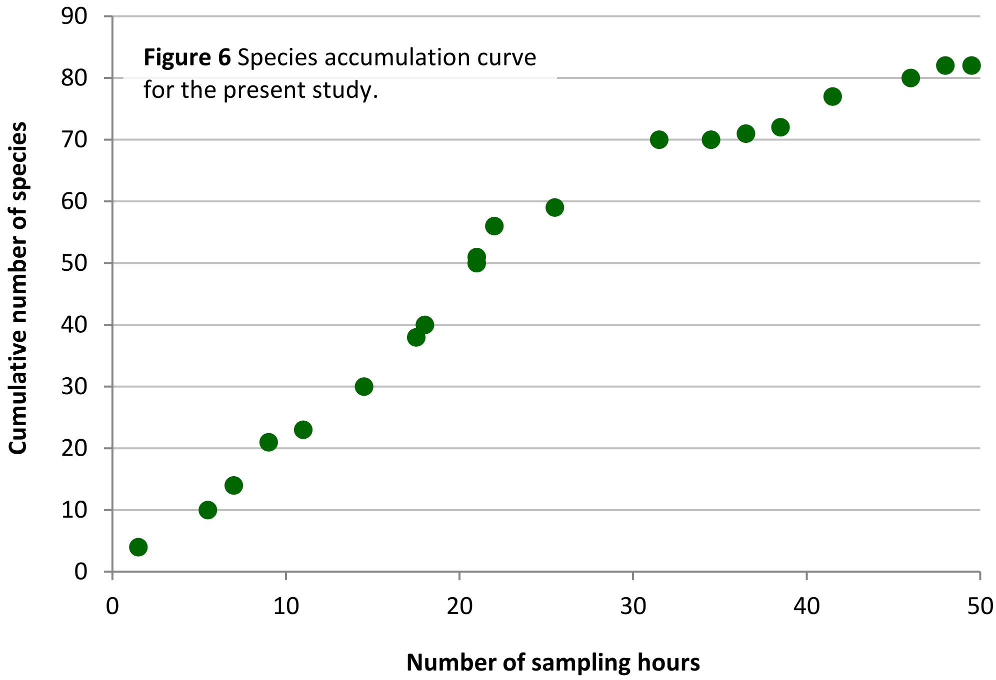

Table 2 Indices of diversity for butterflies at Iracambi, calculated for the sample in the present study.

Index	Formula	Description	Value
Berger-Parker	$d = \frac{N}{N_{max}}$	An intuitively and mathematically simple index. Reciprocal of formula for dominance given in Magurran (1988) to ensure an increase in the value of the index reflects an increase in diversity.	**6.14**
Simpson Diversity	$D = \frac{1}{\sum_{i=1}^{S} P_i^2}$	Heavily weighted towards the most abundant species (i.e. less sensitive to abundances of less common species and total species richness; Magurran 1988).	**24.36**
Simpson Equitability	$E = \frac{D}{D_{max}} = \frac{D}{S}$	Values 0–1, with 1 being complete evenness (where all species are equally abundant).	**0.30**
Shannon Diversity	$H = -\sum_{i=1}^{S} P_i \ln P_i$	Values typically 1.5–3.5, rarely surpasses 4.5 (Margalef 1972) but assumes all species from the community are included in the sample (Magurran 1988).	**3.88**
Shannon Equitability	$J = \frac{H}{H_{max}} = \frac{H}{\ln S}$	Values 0–1, with 1 being complete evenness. Assumes all species from the community are included in the sample (Magurran 1988).	**0.88**

Shared species

Of the 82 species observed in this study, some were also observed in previous studies. The overlap between the present study and previous ones is shown in Table 3. For example, eight species were observed in this study, Ventress (2008) and Coleman (2004), but were not observed in Baliga & Buckley (2001). The five species recorded in all four studies are *Agraulis vanillae*, *Eurema albula*, *Heliconius erato*, *Tegosa claudina* and *Urbanus dorantes*.

There are also many species that were observed in previous studies but not in the present one. For example, 69 species identified in Ventress (2008) were not found in 2012. These species are not listed or analysed further here, but the continual absence of species from future studies (which thoroughly survey the area's diversity) may be cause for concern.

Table 3 Number of species observed in the present study and previous studies of butterflies at Iracambi. SS: shared species.

Present study and…	SS
Ventress (2008)	41
Coleman (2004)	4
Baliga & Buckley (2001)	0

Present study and…	SS
Ventress + Coleman	8
Coleman + Baliga	1
Ventress + Baliga	4
All studies	5

New species

Potentially 30 species were recorded at Iracambi that have not, to the author's knowledge, been recorded in the area before. However, only 19 could be identified to at least genus level with a reasonable level of accuracy. These are listed in Table 4, with an illustrated guide given in Appendix 2. Appendix 2 also gives an indication of the range of qualities of photographs taken: some are clear and allow easy identification whilst others are blurry or pixelated yet are the best shots that could be taken before the butterfly flew away.

Table 4 Species for which new records for Iracambi were made in the present study. List only includes individuals that could be identified to at least the genus level: some potential new records exist in photographs of insufficient quality for species identification.

Actinote pyrrha	*Cogia chalcas*	*Leucidia elvina*
Adelpha cocala	*Colobura dirce*	*Paryphthimoides phronius*
Aeria olena	*Eurema phiale*	*Pseudopieris nehemia*
Apodemia castanea	*Godartiana muscosa*	*Rekoa palegon*
Astraptes sp.?	*Hamadryas arete*	*Taygetis* sp.
Caligo illioneus	*Leptophobia arippa*?	*Theritas trichetra*
Cappronieria galesus		

GIS mapping

All georeferenced records were imported into GIS (Geographic Information System) software for visual display and exploration. DIVA GIS and Google Earth are particularly useful and readily available open source GIS platforms. Google Earth supports .kmz shapefiles (Figure 7), which can be created (via .shp shapefiles) from an Excel spreadsheet of georeferenced records using the DIVA GIS (www.divagis.org). DIVA GIS is a free, open source package useful for spatial analysis of data that may be of interest when further spatial data is collected, on butterflies or other taxa at Iracambi (see Scheldeman & van Zonneveld 2010 for more detail on spatial analysis methods).

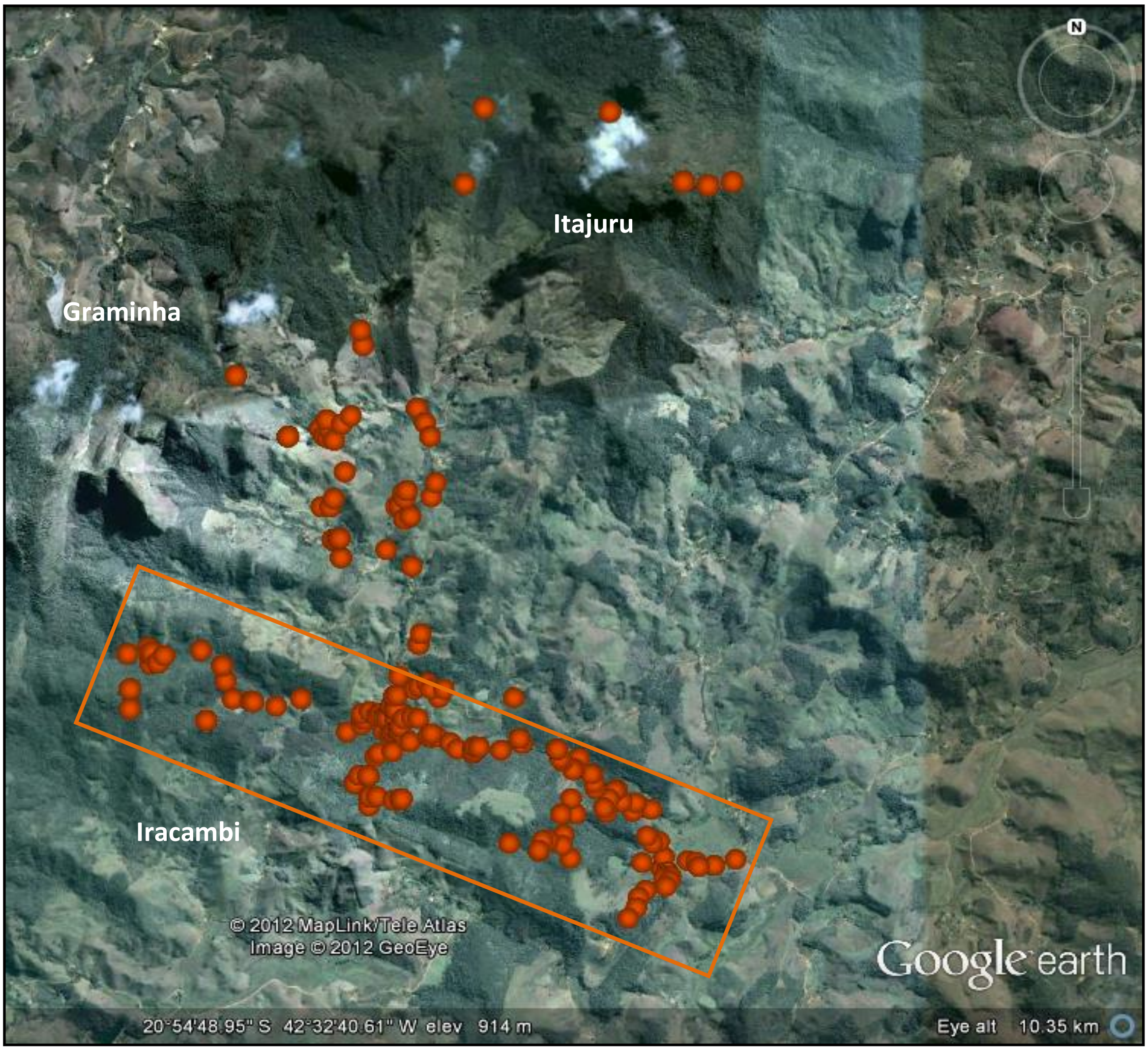

Figure 7 Locations of butterflies sampled at Iracambi in Winter 2012, presented in Google Earth. Most records were within the Iracambi estate, but extended northwards to the new fazenda on the slopes of Graminha, and north west onto the peak of Itajuru.

DISCUSSION

Observed butterfly diversity

82 species were identified with confidence in 2012. However, the present results are far from representative of the total species richness of Iracambi. 63% of the species identified by Ventress (2008) were not seen in 2012. In addition, the species accumulation curve (Figure 6) does not reach the asymptote that would indicate complete characterisation of the community. More sampling hours and/or a more efficient sampling method are necessary to detect a greater number of species, especially rarer ones.

Species richness identified in each of the previous studies of butterflies at Iracambi is summarised in Table 5. It is difficult to compare the overall number of species sampled between this and previous studies of butterflies at Iracambi due to the aims of the studies (e.g. Ventress 2008 aimed to produce a field guide, rather than quantify biodiversity), the different sampling methodologies used and different seasons of sampling.

Table 5 Species richness identified in all four studies of butterflies at Iracambi, although each had a different focus and used different methods.

Study	Date	Approximate species richness	Season
Baliga & Buckley	2001	25 (listed)	June–July
Coleman	2004	27 (caught). Up to c. 60 (author's estimate)	November
Ventress	2008	110 (identified species in field guide) Up to 135 (all images in field guide)	July–August
Present study	2012	82 (identified) Up to 100 (if all identified to species level)	Aug–Sept

In the present study, diversity and evenness of sampled butterflies were both reasonably high, compared to maximum and/or typical values of indices (Table 2). Note that one aim of this study was to sample as many species as possible, meaning evenness and diversity will be somewhat overestimated relative to the sample size.

The real value of indices of diversity and evenness is for comparison across space or time. Thus, they are presented here for comparison with future studies of butterfly diversity at Iracambi in order to monitor diversity change, or for comparison with other areas of *Mata Atlântica* competing for conservation attention. The indices should be used with caution, however. Remember they will be influenced by biases in the sampling methods used (see later), and give equal value to all species. Are rare or beautiful species, for example, more valuable?

It was interesting that the highly managed sugar cane field sampled actually contained a large number of species (13). Unfortunately, this observation is confounded by several factors so should be interpreted carefully and investigated further. First, a long time was spent sampling here (although this was precisely *because* of the activity and diversity of butterflies judged to be present), and species richness is known to be correlated with sampling effort (Gotelli & Colwell 2001). Second, sampling was carried out in the middle of a hot sunny day, when butterfly activity (and conspicuousness) seemed to be greatest across the whole study period. Third, the field is adjacent to a river and vegetated sunny bank, which could also have attracted many butterflies. Coleman (2004) noted the affinity of butterflies for water courses. Individuals did appear to be using the field as a corridor rather than a permanent habitat.

Shared species

It is encouraging that five species (*Agraulis vanillae*, *Eurema albula*, *Heliconius erato*, *Tegosa claudina* and *Urbanus dorantes*) are persisting at Iracambi, having been observed in all studies of the area since 2001. However, we cannot read too much into species that have not been observed in all studies given (i) the low sampling efforts of the earlier studies and (ii) seasonal differences between the studies (Table 5).

In addition to these five species, five more (*Temenis laothoe*, *Danaus plexippus*, *Dismorphia amphonia*, *D. thermesia* and *Hylephila phylaeus*) have been observed in at least this study and Coleman (2004). These studies were conducted in slightly different seasons (August and November, respectively) such that the observation of these ten species in both studies is probably a reflection of the long life span of adult tropical butterflies (Scott 1975).

New species

The discovery of new species for Iracambi is interesting in expanding the known range of Brazilian butterfly species. Species presence records like these are useful for studies looking at the interaction between the environment and species distributions. Furthermore, these new species can augment previous studies to create a more complete field guide for future studies [with the addition of Appendix 2 from this report to Ventress (2008)]. Finally, an increased known butterfly diversity of Iracambi may be of use in bids for conservation support, securing legislative protection or funding for the area.

Spatiotemporal preferences

Butterflies seemed to be most active during the day between 10:00 and 15:30, in agreement with previous studies at Iracambi (Baliga & Buckley 2001, Coleman 2004). However, this was not measured or recorded accurately, and the actual pattern for each species may be more complicated (Peixoto & Benson 2009).

Consistent habitat preferences were noted for certain species. *Hermeuptychia hermes* was most often found on roadsides and disturbed or deforested land. Species in the genus *Anartia* prefer sunny, open habitats such as grassy fields. The tiger Ithomiine butterflies preferred relatively open forest, where light levels are high enough to allow predators to see their bright patterns (Figure 8), whilst clear-winged members of the subfamily (*Hypoleria adasa adasa*, *Ithomia agnosia* and *Pseudoscada erruca*) were found in the lower understorey of the darkest forests, consistent with the findings of Uehara-Prado & Freitas (2009).

Given these observed habitat preferences, the present study also confirms Uehara-Prado & Freitas' (2009) conjecture that the Ithomiine butterflies can be used as indicators of forest quality and disturbance, whilst providing evidence that the mixed land usage of Iracambi may actually promote butterfly diversity across the region (at ground level, at least). That said, the forest areas contain important, unique butterfly diversity and thus are key conservation priorities. Moreover, larger forest areas are needed to support other aspects of biodiversity such as large mammals. Primates such as the woolly spider monkey *Brachyteles arachnoids* and the golden lion tamarin *Leontopithecus rosalia* rely on continuous *Mata Atlântica* but are now Endangered, largely as a result of forest fragmentation (IUCN 2012).

Mimicry

Perhaps the most interesting pattern observed in the field was the occurrence of visually similar individuals in multispecific groups. On the Medicinal Plants Trail (near the Nursery), *Hypothyris ninonia daeta*, *Mechanitis polymnia* and *Placidina euryanassa* were seen together (with *Melinaea ethra* also seen on the trail but not confirmed as being in a multispecies group). On the Waterfall Trail, a group of 100–150 individual *H. ninona daeta*, *M. polymnia* and *M. lysimnia lysimnia* were recorded together (resting above a river crossing, taking flight when disturbed).

All these taxa belong to the subfamily Ithomiinae (Lepidoptera: Nymphalidae) whose unpalatable and aposematic adults are considered key models in many Neotropical mimicry rings (Uehara-Prado & Freitas 2009, Brown & Benson 1974, Beccaloni 1997). If all five taxa are in fact unpalatable, this will be a Müllerian mimicry ring in which numerous toxic species converge on similar warning patterns. Predators therefore only need learn to avoid a single warning patter, reducing the number of each species killed in the learning process (Müller 1879). In this case, these mimics have converged on the orange-black-white 'tiger' colouration (Figure 8).

The present observation (i) adds *Hypothyris ninonia daeta* to the orange mimicry ring proposed by Brown & Benson (1974, their Figure 5; *Placidina eurynassa* was listed as *Placidula euryanassa*) (ii) identifies two novel mimetic combinations *sensu* Moulton (1908) and (iii) is a useful (if anecdotal) example of mimicry at a very fine spatial scale (DeVries et al. 1999). Further investigation into the palatability of these species, as well as further confirmation of this mimicry ring in space and time and possibly quantitative analysis, could be worthwhile.

Figure 8 Three members of the proposed tiger mimicry ring at Iracambi. a) *Melinaea ethra* b) *Mechanitis polymnia* c) *Mechanitis lysimnia lysimnia* d) *Hypothyris ninonia daeta.*

Sampling methodologies

It does appear that photo sampling is an effective method for sampling butterflies, in addition to other sampling methods (hand nets and possibly traps). Coleman (2004) noted that she "observed at least 30 more species but was unable to catch and identify them". With the use of a modern advanced digital camera, these species may have been recorded. In the present study, several species had additional locations recorded by photograph, and for some species the only verifiable record was by photo (such as *Caligo illioneus*, which was too large to catch without damage in the net used, and *Hamadryas arete*, which was only seen once, resting on a tree trunk out of reach and above uncrossable logging debris). Note the use of "verifiable": an advantage of photos is that they provide permanent evidence for further analysis, confirmation or dispute of identification!

Photo sampling will have reduced sampling bias in the present study, allowing the 'capture' of more mobile species and those beyond the reach of the net. Still, somewhat inevitable species bias in the data arises from limited reach of the [net + camera] combination (canopy butterflies were not sampled at all), and spatial bias exists due to sampling along roads and paths.

The butterfly trap used in this study was manufactured on site at Iracambi using scrap materials. Several versions of the trap and baits were tested throughout the project (although only results from the final version are presented). Key features in the design of traps appear to be a narrow neck to prevent escape of captured butterflies, a small distance between the baseplate and the base of the net, and a baseplate slightly overlapping the base ring of the net. Also important in successful trapping are location (where there are sufficient frugivorous butterflies) and attractive bait. The ideal bait for Iracambi has yet to be determined, but the best seems to be fermented banana (banana + baker's yeast) left for 2–3 days in a sunny position. All butterflies trapped were done so with this bait, and one individual of *H. hermes* was observed to be feeding on this bait when left out in an open, sunny position. An alternative bait, suggested by locals, is sugar water.

The bait (and possibly locations or design) of the traps set in this study led to a low diversity of butterflies being caught – the same few species were caught repeatedly. It is not clear to what extent these species are representative of the frugivorous guild at Iracambi, so further sampling would be useful (at the c. 2m trap height used in this study). It would also be very interesting to place traps higher in the canopy of the forest to sample this guild of butterflies and reduce bias in butterfly surveys: butterflies are known to segregated into horizontal strata in tropical forests (DeVries 1988, Dumbrell & Hill 2005) and trapping would be a cheap and harmless way to sample the upper strata at Iracambi.

GIS

This is the first study to record geographical location information with individual species records. If this is continued in the future, with complementary habitat notes, changes in butterfly distributions could be tracked and perhaps linked to climate and land use change. If a particular species of butterfly is of interest, data for this species can be pulled out of the database and examined in a GIS separately.

Note that these are point records of mobile species, reflecting observed locations not entire ranges. Also note that absence of evidence is not evidence of absence: this survey of butterfly locations was by no means thorough and so there will be many locations in which a species does occur but has not been recorded.

Future directions

Butterfly diversity at Iracambi presents many stimulating and enjoyable challenges for future researchers, depending on their interests and skills:

- Re-sample butterfly diversity to determine changes over time;
- Continue to develop the GIS database of butterfly (and/or other taxon) records at Iracambi, and monitor change where possible;
- Investigate the tiger mimicry rings in more detail, perhaps with experiments into the palatability of butterflies to predators and predator choice;
- Develop trapping methodologies to increase number and diversity of butterflies trapped, and sample canopy butterflies.

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APPENDIX 1: Species list

Genus	Species	N
Actinote	*pyrrha*	1
Adelpha	*cocala*	1
Adelpha	*syma*	8
Aeria	*olena*	1
Agraulis	*vanillae*	1
Anartia	*amathea*	7
Anartia	*jatrophae*	7
Apodemia	*castanea*	1
Arawacus	*meliboeus*	2
Arawacus	*tarania*	1
Archeuptychia	*cluena*	4
Archonias	*brassolis*	3
Battus	*polydamas*	2
Calephelis	*brasiliensis*	2
Caligo	*illioneus*	1
Cappronieria	*galesus*	2
Cogia	*chalcas*	1
Colobura	*dirce*	1
Danaus	*gilippus*	4
Danaus	*plexippus*	1
Diaethria	*eluina*	5
Dismorphia	*amphiona*	2
Dismorphia	*thermesia*	1
Dryas	*iulia*	4
Enantia	*lina*	1
Episcada	*carcina*	2
Epityches	*eupompe*	2
Eueides	*aliphera*	2
Eurema	*agave*	1
Eurema	*albula*	8
Eurema	*arbela*	4
Eurema	*deva*	2
Eurema	*elathea*	9
Eurema	*nise*	4
Eurema	*phiale*	1
Godartiana	*muscosa*	5
Hamadryas	*arete*	1
Hamadryas	*epinome*	4
Hamadryas	*februa*	3
Hamadryas	*feronia*	1
Heliconius	*besckey*	1
Heliconius	*erato*	5

Genus	*Species*	*Subspecies*	N
Heliconius	*ethilla*		3
Heliopetes	*alana*		2
Heliopetes	*arsalte*		3
Heliopetes	*macaire*		4
Hemiargus	*hanno*		4
Hermeuptychia	*hermes*		49
Hylephila	*phylaeus*		2
Hypanartia	*lethe*		2
Hypna	*clytemnestra*		8
Hypoleria	*adasa*		3
Hypothyris	*ninonia*	*daeta*	10
Ithomia	*agnosia*		5
Junonia	*evareta*		12
Leptophobia	*arippa*		1
Leucidia	*elvina*		1
Mechanitis	*lysimnia*	*lysimnia*	2
Mechanitis	*polymnia*		5
Melinaea	*ethra*		3
Miltomiges	*cinnamonia*		1
Morpho	*helenor*		4
Pareuptychia	*metaleuca*		1
Pareuptychia	*summandosa*		3
Paryphthimoides	*phronius*		3
Paulogramme	*pyracmon*		2
Philaethria	*wernickey*		2
Phoebis	*argante*		1
Phoebis	*philea*		1
Placidina	*euryanassa*		1
Pseudopieris	*nehemia*		1
Pseudoscada	*erruca*		7
Rekoa	*palegon*		1
Tegosa	*claudina*		10
Temenis	*laothoe*		1
Theritas	*trichetra*		1
Trina	*geometrina*		2
Urbanus	*dorantes*		4
Urbanus	*proteus*		1
Urbanus	*teleus*		8
Vanessa	*myrinna*		6
Xenophanes	*tryxus*		2

N: number of observations of this species

APPENDIX 2: Novel species for Iracambi

Pieridae (yellows, whites and sulphurs) & **Lycaenidae (gossamer-wings)**

Eurema phiale (dorsal)

Eurema phiale (ventral)

Leptophobia arippa?

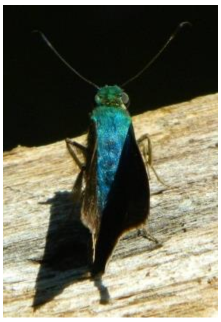
Pseudopieris nehemia

Rekoa palegon

Theritas trichetra

Riodinidae (metalmarks) & **Hesperiidae (skippers)**

Apodemia castanea



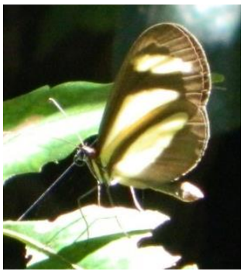
Astraptes sp.?

Cogia chalcas

Nymphalidae (brushfoots) & **Unidentified Species**

Actinote pyrrha

Adelpha cocala



Aeria olena

Caligo illioneus

Colobura dirce

Godartiana muscosa

Hamadryas arete

Paryphthimoides phronius

Satyrinae?

Taygetis sp.

Unknown sp.

Unknown sp.