

## Sampling effort and common species: Optimizing surveys of understorey fruit-feeding butterflies in the Central Amazon

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### ABSTRACT

Surveys on tropical invertebrates must gather as much information as possible over the shortest period, mainly because of financial limitations and hyperdiversity. Fruit-feeding butterflies in the subfamilies Biblidinae, Charaxinae, Nymphalinae and Satyrinae (Nymphalidae) are attracted to decaying material and can be sampled with standardized methodologies, but (1) some groups can be difficult to collect, despite being quite common in Amazonian forest understorey; moreover, (2) the duration of the sampling period is not consistent among studies and (3) the sufficient effort for financially limited projects remains unknown. With this study, we aimed to fulfill points 1–3 in order to recommend a less costly protocol for monitoring purposes in the Amazon. In 25 km<sup>2</sup> of rainforest in the state of Amazonas, Brazil, we evaluated the performance of sampling schemes for these butterflies (four, three, two and one visit in 250 m-long plots), using both nets and bait traps, while considering reductions in sampling effort and the removal of rare and infrequent taxa to optimize field and laboratory work. Reduced-effort schemes are only validated if they reflect both taxonomic and ecological information provided by the maximum effort. Procrustes superimposition was used to estimate the dissimilarity in the spatial distribution of species between schemes. Spatial turnover in herb, liana, palm tree and diameter-at-breast-height > 10 cm tree species composition was used as predictor for the butterfly community through linear regressions. The three-visit scheme was sufficient to retrieve high species similarity and the ecological patterns observed with maximum effort. The two-visit scheme lost a significant amount of information on species composition similarity, but recovered stronger environmental relationships than those observed with the four-visit scheme. The removal of uncommon species did not affect the ecological response of the community, thereby suggesting that common species are driving the spatial patterns of the studied butterflies. Thus, large reductions in costs by reducing sampling effort could be achieved with relatively little loss of information on the species turnover of butterflies and their relationships with the environment. The proposed sampling protocols with reduced effort will allow projects to use their time and financial supply more effectively, showing that cost-effective shortcuts for biodiversity assessments can be useful for conservation, biomonitoring and land use management.

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### 1. Introduction

Conservation and land management policies are designed after diversity and ecological patterns provided by biological surveys (Evans and Viengkham, 2001). Nevertheless, evaluating and measuring species diversity across extensive areas has been a challenge for tropical conservationist studies (Magnusson et al., 2013;

Roberts et al., 2002). An additional problem arises when the targeted organisms are tropical invertebrates (Faith et al., 2001). The greatest obstacles are not only the hyperdiversity and the quantity of material that needs to be worked on (Jiménez-Valverde and Lobo, 2006; Souza et al., 2012), but also the amount of time spent at research sites with poor infrastructure conditions (Santos et al., 2008). As a consequence of these obstacles, the swift responses demanded by environmental assessment and management may become impracticable.

Giving that invertebrates make up most of the biological diversity registered to date (Basset et al., 2012), some sampling protocols aimed at them have been reviewed and readapted in order to facil-

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itate the meeting of deadlines. These readjustments are intended to promote rapid, yet efficient biodiversity surveys, with a view to saving time and money for subsequent studies (Souza et al., 2012), especially in areas under high risk of anthropogenic disturbances. By “efficient”, we mean retrieving as much of the biological information as possible when analysing smaller datasets (Costa and Magnusson, 2010; Santos et al., 2008). Further, these protocols furnish standardized methodologies, which is crucial for different studies to be comparable and applied to integrative biomonitoring-assessment programmes (Costa and Magnusson, 2010; Silveira et al., 2010). In the Amazon, multiple aspects of sampling methods and biological material processing have been simplified in order to determine whether the rarefied information levels capture the patterns observed in the original effort employed. For instance, the use of genus as a surrogate for species (Souza et al., 2016), the redundancy of ant (Souza et al., 2012) and harvestmen (Tourinho et al., 2014) sampling techniques, the reduction in the number of subsamples of ants (Souza et al., 2009), the decrease in sample proportion (Santos et al., 2008) and the removal of uncommon species (Franklin et al., 2013) of edaphic mites all indicate that the optimization of protocols is a feasible purpose.

Among insects, fruit-feeding butterflies are commonly used in faunal surveys, as they are charismatic flagship taxa that display an acknowledged capacity to indicate environmental perturbations (Barlow et al., 2007; Freitas et al., 2003; Schulze et al., 2004). Frugivorous species may represent up to 75% of the richness of four-footed butterflies in the tropics (Brown, 2005), and their diversity patterns are capable of predicting those of trees and birds (Schulze et al., 2004), leading to their inclusion as strategic surrogate taxa in inventories. They are easily sampled with traps containing decaying material as bait, which allows for standardized and simultaneous sampling schemes (DeVries et al., 1997; Freitas et al., 2014; Shuey, 1997). As the capture rate of traps was reported as being very low in the central Amazon (Ribeiro and Freitas, 2012), field time should increase, but the sampling sufficiency for detecting ecological patterns of butterflies in this area remains unexplored. Plus, unless traps are placed at a ~15 cm height, the low-flying Haeterini may be greatly undersampled, even though they are quite common inhabitants of the rainforest understorey (Alexander and DeVries, 2012; Freitas et al., 2014). This limitation left open the possibility of including an active method to complement the sampling design of traps active in the understorey at a height of 1.80–2.20 m. Therefore, we proposed a protocol based on the number of visits to each sampling plot, analogous to that conducted for British butterflies (Roy et al., 2007).

In this context, we aimed at the elucidation of two methodological questions regarding the sampling of Amazonian fruit-feeding butterflies found in the understorey, while testing the reduction in the effort used to recommend a simpler and less expensive protocol. Firstly, can reduced sampling effort schemes (three, two and one visit to each plot) produce a high similarity in species taxonomic composition to the observed maximum one (four visits)? Secondly, can the reduced sampling effort still hold the ecological relationships encountered with the full sampling scheme? In the latter case, the reduced sampling effort includes a decrease in the number of visits per plot, and the removal of rare (singletons) and infrequent species from the multivariate analyses. The ecological relationships of butterflies were investigated using the gradient of plant species composition across space, because vegetation patterns are reported to be important drivers of the distribution of butterfly communities (Barlow et al., 2007; Carneiro et al., 2014; Graça et al., 2015; Ramos, 2000). We hypothesized that by the third visit, we would have collected a representative part of that community of understorey fruit-feeding species compared to four visits, because few different species (very likely rare/infrequent ones) should be added with the fourth visit, resulting in high levels of similarity in species

composition between the three- and four-visit schemes. With half the maximum effort (two visits), we believed sample sizes would be too small to support high species similarity compared to the four-visit scheme, as capture rates of traps could be low (Ribeiro and Freitas, 2012). Because of this, both the three-visit scheme and the successive removal of rare/infrequent taxa should recover the influence of vegetation patterns on butterfly spatial patterns.

## 2. Methods

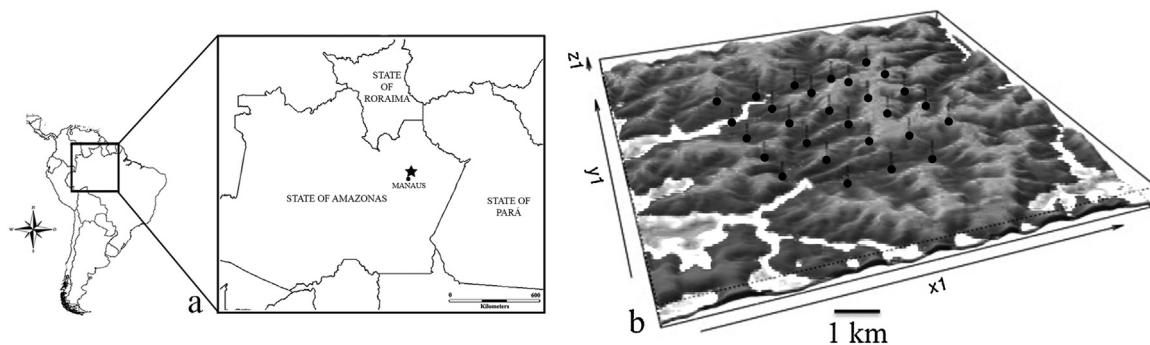
### 2.1. Study site

The field site is located in a 64 km<sup>2</sup> federal-guarded area named Ducke Reserve (02°55' and 03°01'S, 59°53' and 59°59'W) in the north of Manaus city, state of Amazonas, Brazil. The reserve encompasses a typical Amazonian evergreen rainforest, with a shady understorey, abundant in sessile palms (Chauvel et al., 1987; Costa et al., 2009) and with a closed canopy. Because of the urban expansion of Manaus city, Ducke has been turning into an urban forest fragment for the past 15 years, but the forest within the borders has not undergone direct human impact (Baccaro et al., 2008; Costa et al., 2015). Similarly to other tropical landscapes, the terrain forms a mosaic of well-drained clayey highlands, poorly drained sandy lowlands and interjacent slopes (Hodnett et al., 1997). From November to May, rainfall reaches the highest levels (Marques-Filho et al., 1981), and the mean annual temperature recorded between 2008 and 2011 was 25.7 °C (Coordination of Environmental Dynamics, INPA).

### 2.2. Sampling schemes

The sampling design framework utilized in our study follows the system implemented by the Rapid and Long-Term Ecological Project (RAPELD) (Magnusson et al., 2005), which consists of a grid-shaped trail system that gives access to 30 permanent sampling plots (Fig. 1). Each sampling plot consists of one transect (250 m long × 2 m wide) that follows the altitudinal contours to minimize within-plot soil variation, thereby maximizing between-plot variation (Costa and Magnusson, 2010; Magnusson et al., 2005).

We sampled fruit-feeding butterflies from June to August 2013 in 28 plots inside a 25 km<sup>2</sup> area by creating sampling schemes combining bait traps and insect net captures. Traps were baited with liquefied brown sugar (500 mL), plantains (3 units) and bakery yeast (1 tablespoon) after a 24-h fermentation. In each plot, we activated five traps at least 50 m apart and hung by available tree branches at a height of 1.80–2.20 m. We visited the traps every 48 h and always replaced the bait with new 24 h-fermented bait, so the level of rotting of the mixture would not influence the captures between schemes. Traps were left active for eight straight days. The choice of this “effort cap” is based on the fact that eight trapping days was the median amount of field effort utilized in the studies backing up our own research and also met our logistic capabilities and resources. In field experiments, M.B.G. faced difficulties in placing traps at a height of 15 cm to capture Haeterini species, because walking animals often deactivated them by spilling the bait, ripping the trap cloth or knocking them down. In a couple of instances, we even observed South American marsupials trapped inside the devices. So, hand netting was also employed as a way to include low-flying Haeterini in our data set. The plots were visited four times and during each visit, two individuals holding standard 37 cm-diameter insect nets performed the active seeking for 30 min, resulting in a four-day effort for hand nets. The individuals always stayed at least 50 m apart from each other during the sampling window. We always started the active sampling at around 9:00 a.m. and switched the order in which we visited the plots,



**Fig. 1.** Location of Ducke Reserve (filled star) in Brazilian State of Amazonas (a) and the 28 sampling plots (filled dots) in which the sampling was carried out (b). Values of terrain altitude were multiplied by two to better showcase the slopes in the reserve.

so bias due to period of the day (early morning, late morning and early afternoon) and butterfly activity was reduced. Most individuals were collected for identification outside the field, especially the Satyrini, but in a few instances (e.g. *Bia*, *Pierella*, *Tigridia*) individuals were marked and released, as identity could be straightforwardly obtained in the field. We strongly recommend that future investigations dealing with traps and fruit-feeding butterflies check the methodological overview presented by Freitas et al. (2014) prior to field activity.

In our outline, the maximum effort employed was the four-visit scheme, which comprises eight trapping days and active seeking of butterflies for four days (2 h effort). The first rarefaction level (three-visit scheme) gathers information from the first six trapping days and active sampling of three days (1½ h effort). In the two-visit scheme, we analysed the composition of samples from the first four trapping days and two visits with hand nets (1 h effort). Finally, the one-visit scheme includes data from the first two trapping days and the first day of active sampling (½ h effort).

### 2.3. Data analysis

The dimensionality of the butterfly composition data set was reduced by Nonmetric Multidimensional Scaling (NMDS, Minchin, 1987), which is considered a robust ordination method (McCune and Grace, 2002), applied to the Bray-Curtis pairwise distance. Then, we investigated the similarity in species composition between the maximum and the reduced efforts using the Procrustean superimposition procedure (Mardia et al., 1979; Peres-Neto and Jackson, 2001). In this approach, a one-dimension NMDS ordination for the four-visit scheme was fitted to one-dimension ordinations of each reduced scheme separately to test for non-randomness between their configurations. The statistical significance was examined with 1000 Monte Carlo permutations (Manly, 1997; Peres-Neto and Jackson, 2001), while the accepted level of congruence between pairs of NMDS ordinations, measured by the Procrustes correlation ( $R$ ), was  $R > 0.7$  (following Santos et al., 2008). Therefore, we believed that up to 30% of dissimilarity in the spatial distribution of species between maximum and reduced efforts would be a valid protocol for taxonomic aims.

Posteriorly, we tested whether the reduced-effort communities still reflected the ecological patterns observed with the maximum effort. Plant species composition was chosen as a predictor to investigate the spatial ecological patterns of the studied butterflies and this includes data on diameter-at-breast-height > 10 cm trees, herbs, palm trees and lianas altogether (see Castilho et al., 2006; Costa, 2006; Costa et al., 2009; Nogueira et al., 2011 for sampling details). These vegetation data have been collected from exactly the same plots we worked on and have been monitored by studies of the Brazilian Biodiversity Research Programme (PPBio, available

at <http://ppbio.inpa.gov.br>). Long-term monitoring has shown that tree species richness and its correlate, species composition, have stayed equivalent over the years ( $r > 0.97$ , unpublished data, but check Graça et al., 2015). Thus, even though plants and butterflies were not sampled concomitantly, plant species composition is one of the least alterable factors in our study area and temporal integration among data is not problematic.

We utilized the NMDS ordinations as an indicator of butterfly and plant species turnover between plots. The reduced efforts represented (1) a decrease in the number of visiting days, (2) the removal of singleton species and (3) the removal of less frequent species from the analyses. The removal of part of the community (rare/infrequent species) did not infringe the premises for the statistical analyses we performed. On the other hand, if one wishes to run tests that demand a normal distribution of the data, such as diversity indexes, excluding rare species is ill-advised, as the results will be greatly prejudiced. For the first set of reductions, we plotted the NMDS axes of butterfly species composition of the four sampling schemes against the ordination of plant species in linear regression models. Secondly, we removed all singletons from the data set and performed the ordination and regressions as previously. Lastly, we successively removed species occurring on one, two, three and more plots, until we reached a matrix containing the minimum amount of most frequent species necessary to retrieve the species similarity and ecological relationships (*sensu* Franklin et al., 2013). In our case, the smallest data set possible was composed of the nine most frequent species. The resulting ordinations of the reduced communities were plotted against the plant NMDS ordination in regression analyses. The reduced-effort protocols would only be ecologically efficient if the patterns captured with the original sample were still present in the rarefied levels. All p-values were corrected for the false discovery rate, using the robust method "BH" (Benjamini and Yekutieli, 2001). Statistical analyses were run in R software version 3.1.3 (R Development Core Team, 2015), using the vegan 2.2-1 package (Oksanen et al., 2013).

### 2.4. Project costs

Monetary costs were estimated per person per hour for the maximum effort (four-visit scheme) and the simplified protocols. We took into account field and laboratory budgets, including sampling equipment (traps, nets, baits), field assistants' payment, food supply in the field, transportation, and student and technical scholarships granted. We did not incorporate non-perishable laboratory equipment, such as kilns for insect dehydrating, or settling buildings for field staff, as these are highly variable capital costs (Gardner et al., 2008). The United States dollar (as of March 2014) was used as standard currency for financial estimates. The labour time for each scheme was the sum of the time taken for sampling plus the

time for mounting, identifying and tagging all butterflies collected (following Souza et al., 2012, 2016). For both money and time costs, we calculated the relative values (%) of savings.

### 3. Results

We sampled 401 individuals from 41 species of fruit-feeding butterflies belonging to all four subfamilies that comprise the guild (Table 1). Most species were collected exclusively with insect nets (22 species), while 14 were only collected in traps and five through both methods. The four most abundant species were the satyrines *Magneuptychia gera* (Hewitson) and *Bia actorion* (Linnaeus), sampled with both methods, *Pierella astyoche* (Erichson) and *Magneuptychia harpyia* (C. Felder and R. Felder), collected with hand nets only, accounting for 94, 55, 48 and 41 of the individuals, respectively. Together, they represented almost 60% of the total abundance sampled. In the same order, these four species were the most widespread, and occurred in 100%, 79%, 75% and 71% of the sampled plots, respectively. Reduced-effort protocols retained 35 (three-visit scheme), 27 (two-visit) and 21 (one-visit) species from the original sampled community.

Procrustean superimposition showed that the three-visit scheme held high similarity in butterfly species composition compared to the maximum effort ( $R=0.90$ ,  $P=0.004$ ). However, the two-visit and one-visit schemes lost too much information on species composition, and thus were not efficient protocols for beta-diversity studies interested in species similarity patterns (Table 2).

As for the ecological patterns of the butterfly community, regression analyses (Table 2) showed that plant species composition was a good predictor of changes in butterfly composition of the four-visit scheme (Fig. 2a). Then, the three-visit and two-visit schemes maintained the relationship encountered with the maximum effort (Fig. 2b, c), and the latter scheme showed a surprisingly stronger association between butterfly and plant communities. Despite returning an ordination axis, the NMDS for the one-visit scheme warned that the data set was insufficient, thereby already indicating that such an approach was impracticable for any purposes. Predictably, no relationships between plants and butterflies were detected in this case (Table 2).

When we removed all singletons from the analyses, the four-visit, three-visit and two-visit schemes all sustained the butterfly-plant association observed with the maximum effort (Fig. 3). Also, analyses with the removal of infrequent species showed apparent relationships of fruit-feeding butterflies with the vegetation, even with the butterfly community reduced to the nine most frequent species (Table 3).

Since time and money are constraints for sampling extensive tropical areas, the three-visit and the two-visit schemes are reasonable alternatives, as they require considerably less time (17% and 33% reduction compared to the four-visit scheme, respectively) and money (16% and 32% reduction) to sample the same 28 plots (Table 2, Table S1). The scheme with one visit, despite being the least costly in terms of both time (50%) and money (39%), did not prove to be efficient for either species composition similarity or ecological perspectives.

### 4. Discussion

An important issue in devising an effective protocol for surveys of fruit-feeding butterflies is evaluating whether a reduction in sampling effort affects the taxonomic and ecological relationships detected by the maximum effort scheme. In the light of the similarity levels, the comparison between NMDS axes shows how different the spatial distributions of species between schemes are, rather than a sheer comparison of species composition. This means that

we are keeping the complexity of community structuring across the landscape with each reduced effort.

Our results using the three-visit scheme were the most cost-efficient among all reduction levels, as they not only showed high similarity in species distribution compared to the full scheme (90% of similarity, Fig. 2), but also retrieved the ecological patterns initially detected (Fig. 2a vs. b). This scheme removed the singleton species *Chloreuptychia agatha* (A. Butler), *Cissia lesbia* (Staudinger), *Memphis moruus* (F.), *Memphis oenomais* (Boisduval), *Morpho menelaus* (L.) and *Prepona claudina* (Godart) that were sampled on the last visit day. The two-visit scheme lost a substantial amount of information on how the community is distributed across space (49% of similarity to the maximum effort), but was able to portray strong ecological associations between butterfly and plant communities (Fig. 2a vs. c). In fact, the patterns found in this scheme were even stronger than those in the four- and three-visit schemes ( $R^2 = 0.41$ , Table 1), leading us to suppose that the individuals sampled in the last two visits increased the statistical noise in the regression models. Additionally, the removal of all 19 singleton species from the data set in the four-, three- and two-visit schemes (Fig. 3) and the gradual discarding of less frequent species (Table 3) retained the environmental associations, strengthening our supposition that the spatial patterns in the studied butterfly community were driven by the common, frequent species.

The importance of common and rare species to the functionality and structure of species assemblages has been a classic subject among ecologists. There is evidence of niche differentiation between rare and common species of trees, for instance (Lyons et al., 2005; Mi et al., 2012), supporting the important role played by rare species in the goods and services of the ecosystems, even though they occur in a smaller quantity (Gaston, 2012). On the other hand, the common-dominance paradigm attributes a deeper importance to abundant species, since they represent the majority of individuals and biomass in the communities, and thus consume a greater part of the trophic energy (Gaston, 2010, 2012). Additionally, the cascading losses of less common species might be directly influenced by the declines in diversity patterns of common taxa, as the latter are intertwined in many ecological processes and biotic interactions (Gaston, 2010). This has led to the hypothesis that common species might contribute more to ecological responses of communities (e.g. Franklin et al., 2013; Lenat and Resh, 2001), and largely shape their environments (Gaston, 2010).

Generally, conservation biology has underrated common species because rare species are thought to be more susceptible to local and regional extinction (Gaston, 2008). Notwithstanding this, common species are actually the main victims of habitat destruction, large-scale overexploitation and introduced alien species, as their main characteristics – being abundant and widespread – are constantly obstructed by such events (Gaston, 2010). Aligned with that, a growing number of studies have pointed out that common taxa are crucial for the establishment of diversity patterns in several communities (Gaston et al., 2007; Heino and Soininen, 2010; Mora and Robertson, 2005; Rahbek et al., 2007). In addition, the patterns of species richness of common bioindicator taxa (Pearman and Weber, 2007), as well as frequency patterns of insects (Sebek et al., 2012), tended to be more precise in the prediction of community total richness. In the case of butterflies, there has been encouragement for a greater emphasis on butterfly species composition rather than simply on richness/abundance patterns (Barlow et al., 2007). As most studies on surrogate and bioindicator taxa tend to focus on richness-dependent diversity metrics, our documentation of common species driving species turnover across environmental gradients can provide an additional tool in which to integrate ecological studies with faunal monitoring. Such an approach can be especially useful regarding habitat loss and fragmentation threats,

**Table 1**

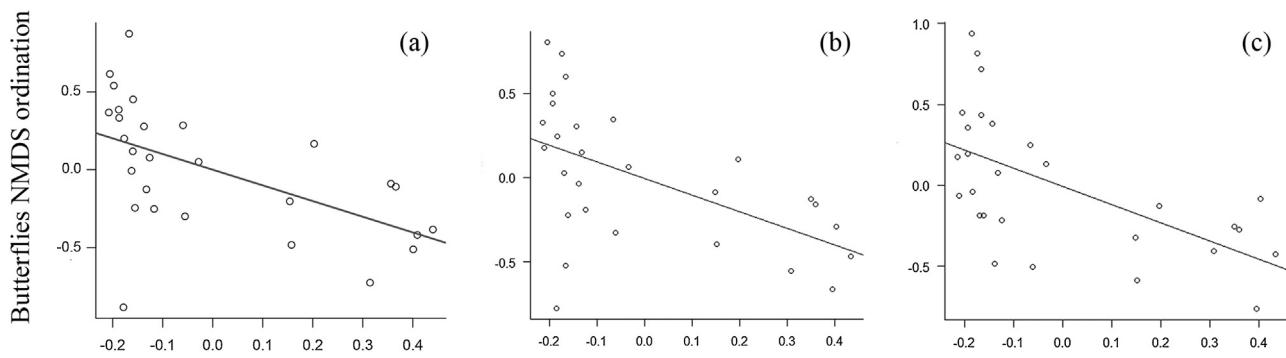
Species of fruit-feeding nymphalids sampled in Ducke Reserve with their respective cumulative abundance. B = sampled with both methods, N = sampled with insect nets, T = sampled with bait traps.

Species	Cumulative abundance per scheme				Sampling method	
	1-visit	2-visit	3-visit	4-visit		
<b>Biblidinae</b>						
Catonephelini						
<i>Catonephele acontius</i> (L., 1771)	1	1	1	2	T	
<i>Eunica veronica</i> H. Bates, 1864	0	0	1	1	N	
<i>Nessaea obrinus</i> (L., 1758)	0	0	2	3	B	
<b>Charaxinae</b>						
Anaeini						
<i>Memphis laertes</i> (Cramer, 1775)	0	0	1	1	T	
<i>Memphis moruus</i> (Fabricius, 1775)	0	0	0	1	T	
<i>Memphis oenomais</i> (Boisduval, 1870)	0	0	0	1	T	
<i>Memphis phantes</i> (Hopffer, 1874)	0	1	2	3	T	
<i>Memphis polycarmes</i> (Fabricius, 1775)	1	1	1	1	T	
<i>Zaretis itys</i> (Cramer, 1777)	1	2	3	4	T	
Preponini						
<i>Archaeoprepona licomedes</i> (Cramer, 1777)	0	1	1	1	T	
<i>Prepona claudina</i> (Godart, [1824])	0	0	0	1	T	
<b>Nymphalinae</b>						
Nymphalini						
<i>Colobura dirce</i> (L., 1758)	0	0	1	1	T	
<i>Tigridia acesta</i> (L., 1758)	0	3	9	14	T	
<b>Satyrinae</b>						
Brassolini						
<i>Bia actorion</i> (L., 1763)	10	23	40	55	B	
<i>Caligo idomeneus</i> (L., 1758)	1	1	1	2	N	
<i>Caligo teucer</i> (L., 1758)	0	0	1	1	T	
<i>Catoblepia soranus</i> (Westwood, 1851)	1	1	1	1	N	
<i>Catoblepia xanthus</i> (L., 1758)	3	3	3	5	B	
<i>Opsiphanes invirae</i> (Hübner, [1808])	0	1	1	1	T	
Haeterini						
<i>Cithaerias andromeda</i> (Fabricius, 1775)	3	4	6	7	N	
<i>Haetera piera</i> (L., 1758)	2	5	9	9	N	
<i>Pierella astyoche</i> (Erichson, [1849])	19	33	40	51	N	
<i>Pierella hyalinus</i> (Gmelin, [1790])	1	1	1	1	N	
<i>Pierella lamia</i> (Sulzer, 1776)	12	23	30	35	N	
<i>Pierella lena</i> (L., 1767)	3	14	20	26	N	
Morphini						
<i>Caerois chorinaeus</i> (Fabricius, 1775)	1	1	1	2	N	
<i>Morpho helenor</i> (Cramer, 1776)	0	2	2	2	N	
<i>Morpho menelaus</i> (L., 1758)	0	0	0	1	N	
Satyrini						
<i>Chloreuptychia agatha</i> (A. Butler, 1867)	0	0	0	1	N	
<i>Chloreuptychia herseis</i> (Godart, [1824])	1	2	4	7	B	
<i>Chloreuptychia marica</i> (Weymer, 1911)	2	3	3	3	N	
<i>Cissia lesbia</i> (Staudinger, [1886])	0	0	0	1	N	
<i>Cissia myncea</i> (Cramer, 1780)	1	1	1	3	N	
<i>Magneuptychia gera</i> (Hewitson, 1850)	37	53	74	98	B	
<i>Magneuptychia harpyia</i> (C. Felder & R. Felder, 1867)	17	27	30	42	N	
<i>Magneuptychia tricolor</i> (Hewitson, 1850)	1	3	4	4	N	
<i>Taygetis cleopatra</i> C. Felder & R. Felder, 1867	1	3	3	5	T	
<i>Taygetis laches</i> Fabricius, 1793	0	1	1	1	N	
<i>Taygetis sosis</i> Hopffer, 1874	0	0	1	1	N	
<i>Taygetis thamyra</i> (Cramer, 1779)	0	0	1	1	N	
<i>Taygetis zippora</i> A. Butler, 1869	0	0	1	1	N	
Total	119	214	301	401		

**Table 2**

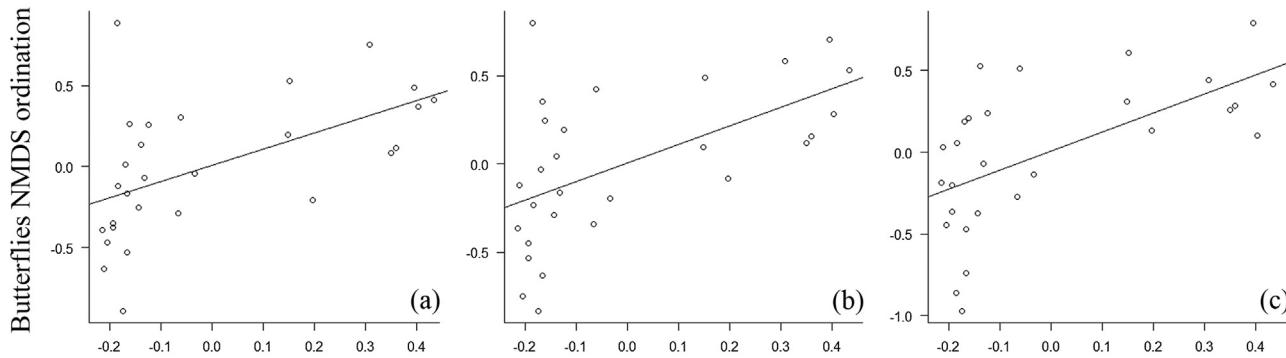
Summary of the results regarding diversity, taxonomic similarity, environmental associations and cost-efficiency for each butterfly sampling protocol. Bold values are statistically significant.  $R^*$  represents the coefficient of the correlation in symmetric Procrustes rotation.

Sampling scheme	Species richness	Similarity in species composition		Ecological patterns with singletons		Ecological patterns without singletons		Cost (%)	Time (%)
		$R^*$	$P$	$R^2$	$P$	$R^2$	$P$		
Four visits	41	–	–	0.33	<b>0.024</b>	0.32	<b>0.024</b>	100	100
Three visits	35	0.90	<b>0.004</b>	0.29	<b>0.029</b>	0.31	<b>0.024</b>	84	83
Two visits	27	0.49	<b>0.030</b>	0.41	<b>0.005</b>	0.41	<b>0.005</b>	68	67
One visit	21	0.21	0.307	0.03	0.680	0.03	0.680	61	50



Plants NMDS ordination

**Fig. 2.** Effect of the gradient of plant community in butterfly species turnover collected with the four-visit (a), three-visit (b) and two-visit (c) schemes.



Plants NMDS ordination

**Fig. 3.** Influence of plant species turnover in communities (removal of singletons) of butterflies sampled in the four-visit (a), three-visit (b) and two-visit (c) schemes, which were the ones depicting patterns of spatial distribution.

since our study area is among the highly endangered continuous forests of the central Amazon.

Working with reduced quantities of information may not be as problematic as most would cogitate. For example, the removal of rare species of tropical bats generated great similarity in species composition between full and truncated data sets (Meyer et al., 2015), while common species of Swiss butterflies accounted for most of the influence on patterns of species richness (Pearman and Weber, 2007). As for the retrieval of spatial patterns, the exclusion of unidentified morpho-species of South American trees did not affect the ecological response of the community (Pos et al., 2014), and in Canadian aquatic environments, the omission of 125 species of diatom algae with a relative abundance < 2% still portrayed the occurrence patterns that differentiated disturbed from undisturbed areas (Lavoie et al., 2009). The congruence of these outcomes, in line with the ones presented here, indicates that such approaches can be explored more deeply and across several biological systems, while revealing that one does not necessarily need to perform exhaustive collecting of material to obtain a solid data set and evident ecological information (refer to Tables 2 and 3). Also, most tropical arthropod assemblages comprise a high percentage of infrequent and undescribed species, which often leads to identification of many morpho-species. If this surrogate capacity of common species is a global pattern among arthropods, monitoring surveys in the tropics can be facilitated, as one would not be required to identify all rare species in diverse groups. Finally, for fruit-feeding butterflies in particular, local people can be trained to identify the most common species (parataxonomists), as well as mark and release them in long-term monitoring programmes.

**Table 3**

Results of the environmental relationships of the butterfly community with the successive removal of the least frequent species, until the dataset was reduced to nine species. Bold values are statistically significant.

Number of species in the dataset	R <sup>2</sup> for the NMDS ordination of plants	P
22	0.189	<b>0.036</b>
18	0.187	<b>0.036</b>
13	0.175	<b>0.040</b>
12	0.167	<b>0.040</b>
9	0.165	<b>0.040</b>

In the context of tropical forests, which are acknowledged as costly locations for carrying out biodiversity surveys (Lawton et al., 1998), financial support must be used as efficiently as possible (Gardner et al., 2008). The sampling protocols proposed here represent a decrease in the period of activities in the field, which perhaps is the strongest limitation of surveys with fruit-feeding butterflies, since laboratory tasks usually do not demand much time. These cost-benefit meliorations of the protocols enable surveys to be conducted in hard-to-access areas where the field staff cannot stay for long periods, a common situation in the Amazon Basin. Studies dealing with biodiversity assessment need such practical and clear implications for their results, as a way to strengthen conservation biology inside the scientific community and maintain the support from incentive foundations (Cleary, 2006).

## 5. Conclusions

In summary, we suggest that a three-visit scheme is sufficient to meet both the taxonomic and ecological requests of a fruit-feeding butterfly survey in the central Amazon. If the projects do not necessarily require maximized diversity or species lists, even a two-visit scheme can be a reasonable alternative to achieve ecological responses regarding the fruit-feeding butterfly community. The rarefaction levels also showed that the most abundant and frequent species operated as surrogates for the entire community regarding the detection of spatial distribution patterns, and such an approach can be further employed with multiple taxa and habitats to generate integrative outcomes. Together, these elements can optimize the studies of butterflies in the Amazon and accelerate the responses needed from environmental assessments. In spite of this, we argue that this higher importance given to common species only concerns optimization for surveys in biomonitoring, and rare/infrequent taxa must still be considered in studies on community ecology in general and conservation efforts. As for the time and financial restrictions, the proposed schemes permit savings in both aspects, which can be important in redirecting spare resources to posterior surveys. This is the central motivation for why we should try to analyse a reduced dataset. In the end, we believe that the efforts of ecologists should be united to promote biodiversity conservation in all global landscapes.

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## Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at <http://dx.doi.org/10.1016/j.ecolind.2016.09.040>.

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