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Active Sampling and Understory Traps Can Cost-Effectively Detect Changes in Butterfly Communities after Hydroelectric Dam Construction

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Abstract: (1) Background: Monitoring programs are essential to conservation but are often restricted by limited financial resources. Optimal monitoring can lead to higher cost-effectiveness. (2) Methods: In this study, we used butterflies as bioindicators to assess the effects of filling a dam in the Brazilian Amazon. We studied the effects of flooding on butterfly assemblages through samples collected before and after the flooding. We contrasted three sampling techniques: baited traps in the (a) canopy and (b) understory and (c) active collections using entomological nets. (3) Results: Community composition showed low resistance, with pronounced changes after disturbance, and low resilience, with the failure to recover taxonomic diversity even after two years. We found that using the three techniques together was redundant and baited understory traps alone were sufficient to detect community changes. (4) Conclusions: Our study adds to the currently limited knowledge about the effects of hydroelectric plants on terrestrial insect fauna. In addition, identifying cost-effective monitoring, which is often lacking in conservation studies, allows projects to use time and financial resources more efficiently, particularly given the financial limitations available for conservation studies in tropical countries.

Keywords: Amazonia; biomonitoring; Lepidoptera; optimal monitoring; tropical rainforest

Citation: Santos, A.d.C.; Carmo, D.L.R.d.; Plaza, T.G.D.; Arrua, B.A.; Nacagawa, V.A.F.; Fernades, R.A.M.; Pontes, F.T.N.; Ribeiro, D.B. Active Sampling and Understory Traps Can Cost-Effectively Detect Changes in Butterfly Communities after Hydroelectric Dam Construction. *Diversity* **2022**, *14*, 873. https://doi.org/10.3390/d14100873

Academic Editor: Luc Legal

Received: 24 September 2022
Accepted: 13 October 2022
Published: 16 October 2022

1. Introduction

Providing renewable energy has become one of the most important developmental strategies worldwide to reduce greenhouse gas emissions [1,2]. Hydroelectricity has been the world's largest renewable energy source and in order to achieve clean energy targets, hydroelectric energy production is expected to increase considerably in the next decades, especially in developing countries [3]. Brazil, for example, has a large hydroelectric dam construction program, most of which is concentrated in the Amazon region [2,4]. However, the construction of large dams is often a controversial management decision. In spite of providing renewable energy and consequently economic benefits, the construction of dams and the concurrent flooding of large areas can lead to environmental losses that are often neglected [3,5].

Studies on the effects of hydroelectric plants are scarce and generally assess social and economic impacts [6–8]. When conducted, environmental impact assessments largely focus on aquatic organisms [9–12]. The few studies on terrestrial organisms concentrate mainly on the effects of insularization that occurs after filling the dam [13–15]. Thus, our knowledge is lacking about the effects of dams on terrestrial organisms, with few accurate before-after comparisons [16,17].

Hydroelectric dams alter the availability and level of the river water, as well as the depth of the water table, and reduce the flood pulse, thereby affecting terrestrial habitats [18]. With the filling of the dam, nearby riparian vegetation becomes permanently flooded and the groundwater level in the non-flooded area decreases, modifying the original vegetation [19]. These changes may affect the abundance and distribution of terrestrial species associated with wetlands, but the extent of these effects of the new habitat type in the unflooded areas is poorly understood [16,20].

Monitoring programs are essential for conservation but are limited by financial resources. Therefore, rapid and robust (and consequently cheaper) methods can reduce short-term biodiversity loss [21]. In general, invertebrate research should gather as much information as possible in the shortest time, given the short life cycle of invertebrates and their sensitivity to environmental changes [22]. Effective and cheap sampling techniques allow projects to get the maximum amount of useful data per dollar expended [23]. However, most conservation studies do not explicitly assess the cost-effectiveness of their methods, at the risk of losing funding agency support and creating a barrier to conservation opportunities [24,25].

Bioindicators are often used to evaluate environmental impacts. Fruit-feeding butterflies, for instance, respond rapidly to small environmental changes and their taxonomy is well-defined [26–28]. Fruit-feeding butterflies are also easy to capture by attraction to bait traps, which allows for standardized and simultaneous sampling schemes. Butterfly communities in Amazon are good models for impact detection by logging [29], wildfires [30], and land-use changes [31]. They are mainly composed of Charaxinae, Satyrinae, Biblidinae, and some genera of other subfamilies of Nymphalidae [31]. However, a study in Central Amazonia reported very low trap capture rates and suggested using entomological nets to capture insects actively in order to complement baited traps [32]. Furthermore, most tropical rainforest butterflies exhibit vertical stratification and stratified sampling has been the best approach to studying community structure [23]. However, butterflies in the understory may be more affected by forest disturbance than those in the canopy [23,33,34]. These studies suggest that understory sampling alone could be an effective way to monitor the impacts of hydroelectric projects. Given the limited financial resources, evaluating the cost-effectiveness of sampling to detect environmental disturbance becomes essential.

Thus, considering the scarcity of information on the impacts of hydroelectric plants on terrestrial organisms and the need to identify the most cost-effective sampling technique, this study aimed to (a) assess whether flooding of the Santo Antonio dam affected the butterfly community along the Madeira River and (b) identify how different sampling techniques reflected the effects of flooding. The Madeira River is the main tributary of the Amazon River and the Madeira River sub-basin is one of the most threatened areas in the Amazon, with 40 hydroelectric dams already functioning or under construction [35].

We studied the effect of flooding of the Santo Antônio dam on the structure of butterfly assemblages through samples collected a year before (Pre-stage), immediately after (PostIm-stage), one year (Post1-stage), and two years (Post2-stage) after flooding. We hypothesize that: (a) the flood affects the structure (richness, composition, and β-diversity) of butterfly communities in the area around the dam; (b) these changes occur immediately after the flooding; (c) the effects of flooding are stronger on butterfly communities closer to the river; (d) the perceived community will differ based on the sampling method, that is, traps in the understory, in the canopy, or active netting.

2. Materials and Methods

2.1. Study Site

The study site was located in the southwestern part of the Brazilian Amazon, in Porto Velho Municipality, Rondônia State (Figure 1). The Santo Antônio Hydroelectric dam is located 10 km upstream on the Madeira River from the city of Porto Velho. The dam has been operating since March 2012, and with 3150 MW of installed capacity, it is the fourth largest hydroelectric dam in Brazil [36]. We sampled fruit-feeding butterflies in four areas near the dam (08°48′ S; 63°57′ W).

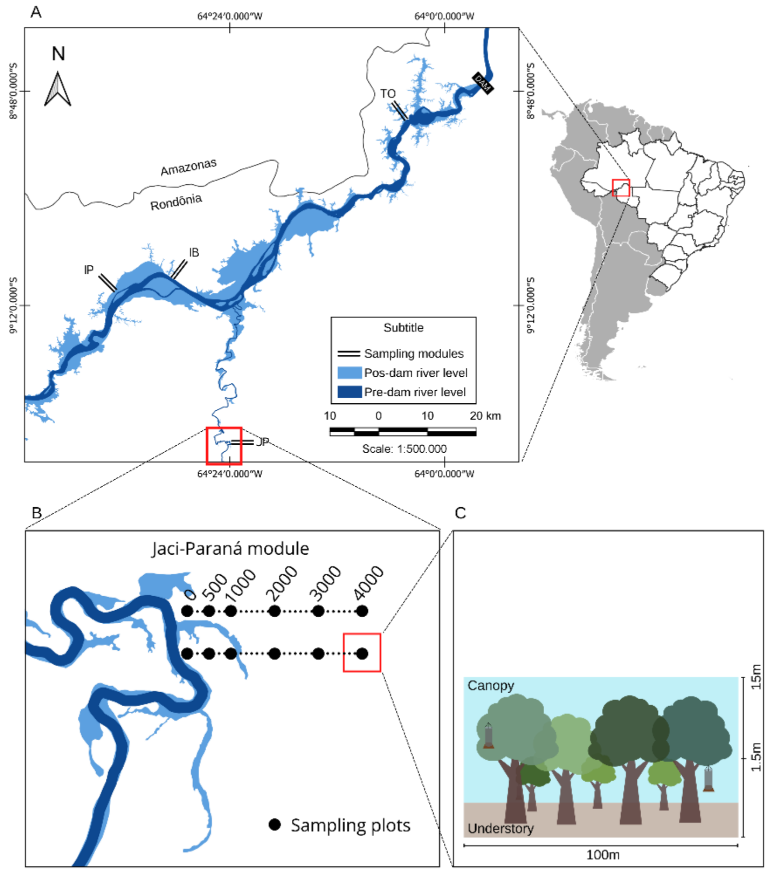

Figure 1. Location of the study area showing the four sampling sites along the Madeira River, in southwestern Amazonia, Brazil. (**A**) Teotônio (TO), Ilha de Búfalos (IB), Ilha das Pedras (IP), Jaci Paraná (JP), (**B**) A sampling site with two 5-km transects and six plots (black circles) at 0, 500, 1000, 2000, 3000 and 4000 m from the bank of the Madeira River (**C**) A plot with a trap in the understory and in the canopy 100 m apart.

The vegetation of the study area consisted mainly of typical Amazonian forest formations, open ombrophilous forest (dominant), and dense ombrophilous forest [17]. According to the Köppen classification, the predominant climate is Aw—Tropical Rainy. The average annual temperature was 25–27 °C and the annual precipitation was 1400–2000 mm between 1998 and 2007. The dry season generally occurs from June to September and the rainy season from November to April, with >330 mm monthly precipitation in December and January. River levels can vary by more than 12 m in some parts of the upper Madeira River [37].

2.2. Sampling

Four sampling modules were installed 10–100 km upstream of the dam. The configuration of the modules followed the RAPELD biodiversity survey method developed by the Biodiversity Research Program (PPBio) [38]. Three modules were located on the left bank of the Madeira River, in Teotônio (TE), Ilha de Búfalos (IB) and Ilha das Pedras (IP), and one on the right bank of the Jaci-Paraná River (JP), an affluent of the Madeira River (Figure 1a). Each module consisted of two 4-km parallel transects perpendicular to the Madeira River, separated by 1 km. We installed six plots along the two transects, 0, 500, 1000, 2000, 3000, and 4000 m from the original river bank (Figure 1b).

Butterfly sampling was carried out between October 2010 and November 2014 in 16 surveys. The dam was filled in March 2012. We sampled butterflies during the pre-filling in October 2010 and January, April, June, September, and November 2011. After filling, we sampled in March and June 2012 (immediate post-filling; (Post1), a year later in January, April, July, and October 2013 (post-filling 1); and two years later in January, April, August, and November 2014 (post-filling 2). We used three sampling techniques: passive butterfly sampling using baited traps in the (1) canopy and (2) understory and active sampling using (3) entomological nets.

2.3. Passive Butterfly Sampling

In each module were installed 24 modified Van Someren-Rydon traps, 12 in each of the two transects. Each trap was baited with banana and papaya that had been fermented in beer and sugar for 48 h [29]. Canopy traps were suspended from branches of emerging trees using synthetic ropes at a height of 8–20 m, while understory maps were located 1.5 m above ground (Figure 1c). The traps remained in the field for 12 days and were baited and checked every 48 h to refresh the baits and capture butterflies. The total effort was 1.432 trap days (16 samples × 96 traps × 12 sampling days).

The collected specimens were identified with the help experts, and consulting the collections of the Federal University of Rio Grande do Sul (UFRGS) and the Museum of Zoology of the University of São Paulo (MZUSP) as reference.

2.4. Active Butterfly Sampling

Butterfly sampling was using the metodo-modified Pollard transects [39]. Active collection was carried out along the length (4000 m) of one transect in each plot. We captured butterflies attracted by the bait using an entomological net on the second field day, once per plot. Sampling was standardized to four person-hours per module, with two researchers collecting at the same time for two hours. The total effort was 512 h (16 samples × 4 transects × 2 persons × 4 h).

Specimens were labeled and identified following the same protocol as for butterflies from the passive collection.

2.5. Data Analysis

We used rarefaction curves with interpolated and extrapolated components to compare richness between filling stages (Pre, PostIm, Post1 and Post2), sampling technique (canopy traps, understory traps and entomological nets) and distance from the river (0, 500, 1000, 2000, 3000 and 4000 m). The extrapolation curves indicated that the 95% confidence intervals converged. The curves were constructed based on Hill's number $q = 0$ (species richness), $q = 1$ (the exponential of Shannon's entropy index), and $q = 2$ (the inverse of Simpson's concentration index) [40]. We applied bootstrapping to produce 95% confidence intervals for the rarefaction curves [40,41].

To determine if flooding affected species composition, we assessed the effect of time after filling and distance from the river, using the multivariate extension of generalized linear models by applying the *manyglm* function in the *mvabund* package [42]. This model-based approach allows for hypothesis testing, and unlike distance-based methods, it can distinguish location and dispersion effects due to the misspecification of the mean–variance relationship [43]. We used the *offset* argument of the *manyglm* function to control for differences in sampling effort between flooding categories. We evaluated the effect of flooding on the assemblages using the *anova.manyglm* function, which resamples the fitted model using "pit-trap" bootstrapping to resample abundance data, while accounting for correlations among species. The p-value was calculated from 999 bootstraps. Then we apply the FDR (False Discovery Rate) criterion that allows the control of false positives. We conducted pairwise comparisons between flooding categories using the *pairwise.comp* option of the *anova.manyglm* function. We fitted a multivariate generalized linear model with flooding categories as the predictor variable. We used abundance data as response variables and analyzed them using negative-binomial distribution, as well as occurrence data, analyzed using binomial distribution in the *mvabund* analyses. For multivariate abundance data, it has been shown that the negative binomial distribution is a good choice of model for counts and binary (presence/absence) data, binomial should be used [43].

To evaluate the effect of dam filling on butterfly species composition in a bi-dimensional space and to represent the different sites, we applied ordination using the *ecoCopula* package [44]. This package allows visualization of multivariate data (abundance or occurrence) with ordination using model-based methods (rather than distance-based, such as nMDS). We used the *cord* function that works on *manyglm* objects that were the output of the *mvabund* package to visualize the distribution of samples along several latent variables, representing an unobserved environmental gradient [44].

We used the Procrustes overlap to estimate the dissimilarity in the spatial distribution of species among the three sampling techniques [45] using the *protest* function of the *vegan* package. We fitted a one-dimensional ordination of the understory sampling to the one-dimensional canopy and entomological net ordinations to test the non-randomness between their configurations. The comparison between the axes showed the difference in the spatial distribution of species among sampling methods, as opposed to simply differences in species composition. In this way, we could maintain community complexity in each type of sampling. Statistical significance was examined with 1000 Monte Carlo permutations [45].

We used β-diversity partitioning to determine the dominant pattern of temporal changes between flooding categories [46]. Using this method, we separated compositional differences among communities into three complementary components: similarity (S), which measures the lack of β-diversity between two sites (e.g., the degree of shared species between two sites), abundance difference (D), which indicates how differences in abundance contribute to differences in β-diversity and replacement (R), which measures how frequently species are substituted along an ecological gradient. We performed the decomposition of β-diversity based on the Ruzicka Dissimilarity Index using the *beta.div.comp* function of the *adespatial* package [47]. The Ruzicka Dissimilarity Index corresponds to the Jaccard coefficient for quantitative data but its interpretation is more intuitive [46]. Using the SDR-Simplex method through the *triangle.plot* function of the *ade4* package [48], we produced ternary plots to visualize the relative contribution of the three components (S, D, and R) of β-diversity. In the ternary plots, larger dots inside the triangle represent the average of the components and smaller ones represent all pairs of plots.

We also estimated the time necessary in the field for each sampling technique, as a proxy of cost from the total sampling time and the time requirements for installing traps. We then calculated costs using relative (%) working hours to compare the three sampling techniques.

All analyses were conducted in R statistical software, version 4.1.3 [49].

3. Results

We recorded 2555 individuals of 144 butterfly species recorded in 58 genera and 8 subfamilies (Limenitidinae, Charaxinae, Satyrinae, Ageroniini, Biblidinae, Nymphalinae, Apaturinae, and Cyrestinae) all from the Nymphalidae family (Supplementary Material Table S1). Based on the individual number-based rarefaction curves, richness and diversity were significantly higher before the flood (Figure 2a–c), however, diversity appears to reestablish 1 year after the impact (Figure 2b,c).

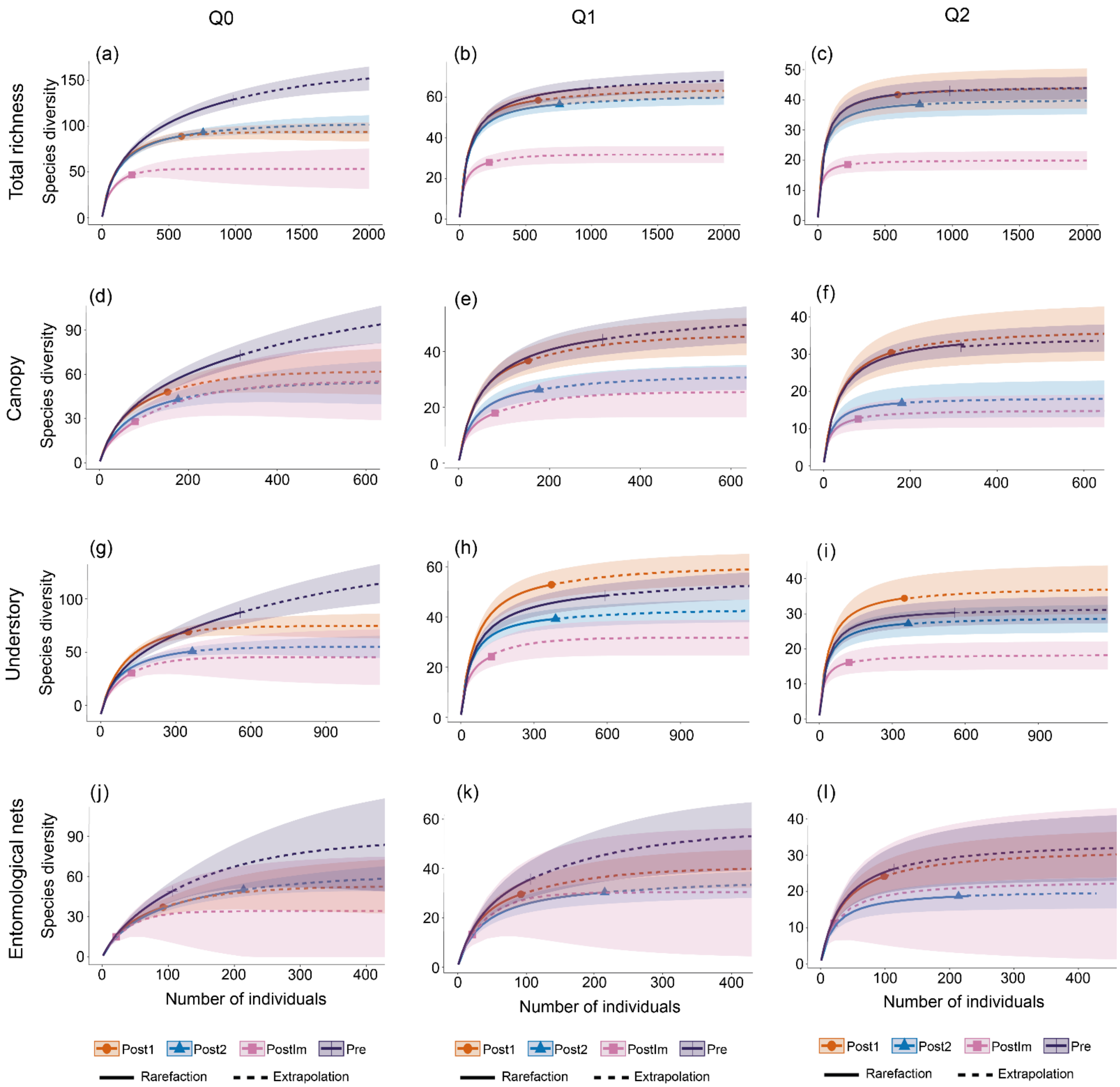

Figure 2. Individuals number-based rarefaction and extrapolation curves for butterfly communities before (Pre), immediately after (PostIm), one year after (Post1), and two years after (Post2) the filling of the Santo Antônio dam on the Madeira River in southwestern Amazonia, Brazil based on the thee sampling techniques (**a**–**c**), canopy traps (**d**–**f**), understory traps and (**g**–**i**) and entomological nets (**j**–**l**). 95% unconditional confidence intervals are shown by shading, based on bootstrapping with 1000 replications. Each curve is extrapolated to twice the maximum size of the largest sample.

Regarding the sampling methods, only the understory sampling detected a higher pre-filling richness than the richness estimated at post-flood stages (Figure 2e). In general, the number of species collected by the three methods was also similar based on extrapolation, indicating that the sampling method did not affect perceived species richness (Figure S1; Table 1a). Furthermore, there was no difference in the number of species at different distances from the river.

Table 1. Butterfly species richness and composition including occurrence and abundance data collected between October 2010 and November 2014 in the Santo Antônio dam on the Madeira River in southwestern Amazonia, Brazil. (a) Comparisons among flooding stages and (b) among sampling techniques.

Analysis	Sampling Techniques	(a) Flood Stages				(b) Sampling Techniques
		Pre	PostIm	Post1	Post2	
Richness	Canopy	-	-	-	-	A
	Understory	↑	↓	↓	↓	A
	Nets	-	-	-	-	A
Composition Occurrence	Canopy	A	B	-	-	-
	Understory	A	B	C	D	A
	Nets	-	A	-	B	B
Composition Abundance	Canopy	A	B	C	D	A
	Understory	A	B	C	D	-
	Nets	A	B	C	D	B

As for diversity, the entomological nets were the least efficient method to capture changes in the community (Figure 2j–l), unlike the canopy, which showed that the community, despite recovering diversity after 1 year, this diversity decreases after 2 years (Figure 2e,f).

Based on the multivariate general linear model, the community showed a significant difference between the pre- and post-flood composition. The understory captured well the differences in species composition between the inundation stages for both occurrence (Table 2a) and abundance (Table 2b) data. On the other hand, the canopy and net methods did not detect changes in composition based only on incidence, which suggests that metrics based on abundance are more robust.

Table 2. Pairwise comparisons (manyglm analysis) of the association between the structure of the butterfly assemblages using occurrence (a) and abundance (b) data collected between October 2010 and November 2014 in the Santo Antônio dam on the Madeira River in southwestern Amazonia in Brazil in four different flooding stages were Pre, PostIm, Post1 and Post2 using three sampling techniques Canopy, Understory, and Entomological nets. * indicates significant results.

(a)	Canopy			Understory			Entomological Nets		
	Statistic	*p*-Value	*p*-Ajust	Statistic	*p*-Value	*p*-Ajust	Statistic	*p*-Value	*p*-Ajust
PostIm–Pre	203.2	0.023 *	0.138	313.5	0.007 *	0.042 *	153.4	0.049 *	0.2940
Post2–Pre	171.9	0.058 *	0.174	286.1	0.015 *	0.045 *	152.1	0.052 *	0.1560
Post1–Pre	159.7	0.063	0.126	279	0.015 *	0.030 *	139.4	0.052 *	0.1040
Post1–PostIm	140.2	0.063	0.095	242.6	0.015 *	0.023 *	112.6	0.096	0.1440
Post1–Post2	139.5	0.063	0.076	215.3	0.015 *	0.018 *	107.2	0.096	0.1152
Post2–PostIm	118.8	0.063	0.063	207.3	0.015 *	0.015 *	102.8	0.096	0.0960
(b)	Canopy			Understory			Entomological Nets		
	Statistic	*p*-Value	*p*-Ajust	Statistic	*p*-Value	*p*-Ajust	Statistic	*p*-Value	*p*-Ajust
PostIm–Pre	230.1	0.011 *	0.066	346.9	0.002 *	0.012 *	195.2	0.011 *	0.066
Post2–Pre	224.8	0.011 *	0.033 *	339	0.002 *	0.006 *	188.1	0.011 *	0.033 *
Post1–Pre	210.1	0.011 *	0.022 *	323.7	0.002 *	0.004 *	178.5	0.011 *	0.022 *
Post1–PostIm	179.8	0.011 *	0.017 *	265.5	0.003 *	0.005 *	150.4	0.011 *	0.017 *
Post1–Post2	171.4	0.011 *	0.013 *	256.1	0.003 *	0.004 *	138.1	0.011 *	0.013 *
Post2–PostIm	144.4	0.011 *	0.011 *	242.2	0.003 *	0.003 *	124.4	0.011 *	0.011 *

The species compositions differed among stages of flooding in the understory (Table 2a). The butterflies in different stages and strata differed based on occurrence data (Figure 3b). On the other hand, we detected a difference between Pre and PostIm based on canopy traps and between PostIm and Post2 based on active netting (Tables 1 and 2a). For the abundance data, the modeling results showed different species compositions among inundation stages and among the three types of sampling (Tables 1 and 2b; Figure 3d,e). We found no difference in composition between points along the gradient of distance from the river at any stage or type of sampling for neither occurrence nor abundance data.

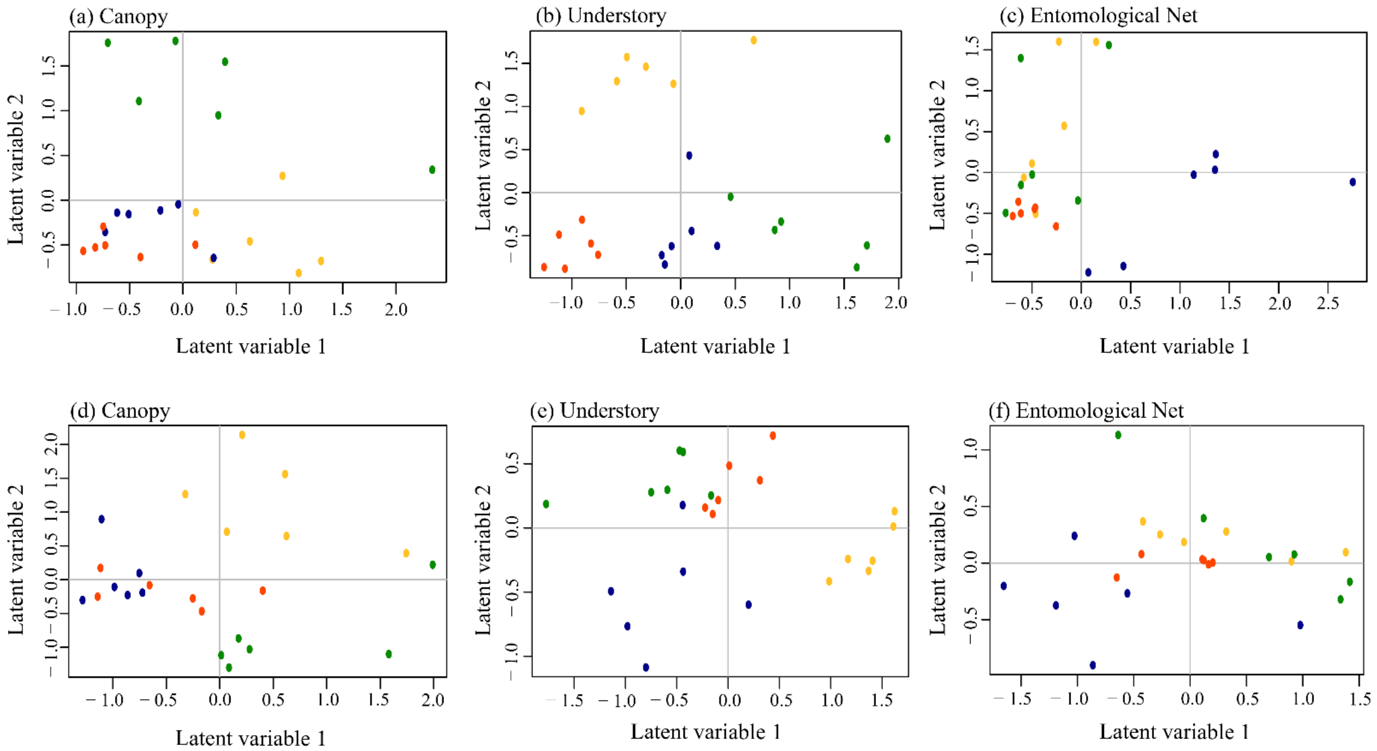

Figure 3. EcoCopula ordination based on occurrence (**a**–**c**) and abundance data (**d**–f) of butterfly species before (Pre = green), immediately after (PostIm = red), one year after (Post1 = yellow) and two years after (Post2 = blue) the creation of the Santo Antônio dam on the Madeira River in southwestern Amazonia, Brazil. Latent variables (unobserved environmental gradients) are shown for three different sampling techniques: canopy, understory, and entomological nets. The dots represent distances from the river 0, 500, 1000, 2000, 3000, and 4000 m.

Regarding community changes, the β-diversity for the canopy and understory were similar, based on the SDR (Figure 4). We found a low average similarity (57%) between Pre and PostIm stages. This dissimilarity was mainly (about 28%) driven by abundance differences between the stages. However, the similarity increased over time, reaching on average 45% after two years based on the active sampling. On the other hand, in the understory, the community showed the largest change immediately after the flood, compared to the canopy samples at the same time, and although the similarity increased after two years due to increased abundance, the replacement rate remained high, around 41%. Considering the effects of the sampling technique, understory sampling and entomological nets led to different results for occurrence and abundance data ($R^2 = 0.38$, $p = 0.04$) and there was a difference between canopy sampling and entomological nets ($R^2 = 0.39$, $p = 0.05$). However, we found no differences between the canopy and understory sampling ordinations for neither occurrence ($R^2 = 0.78$) nor abundance data ($R^2 = 0.65$), indicating a lack of stratum effects (Table 1).

The installation of understory traps was about 80% less time-consuming than canopy traps and checking them also took 50% less time. As active netting was opportunistic between the checking of traps, this method did not significantly increase the sampling time.

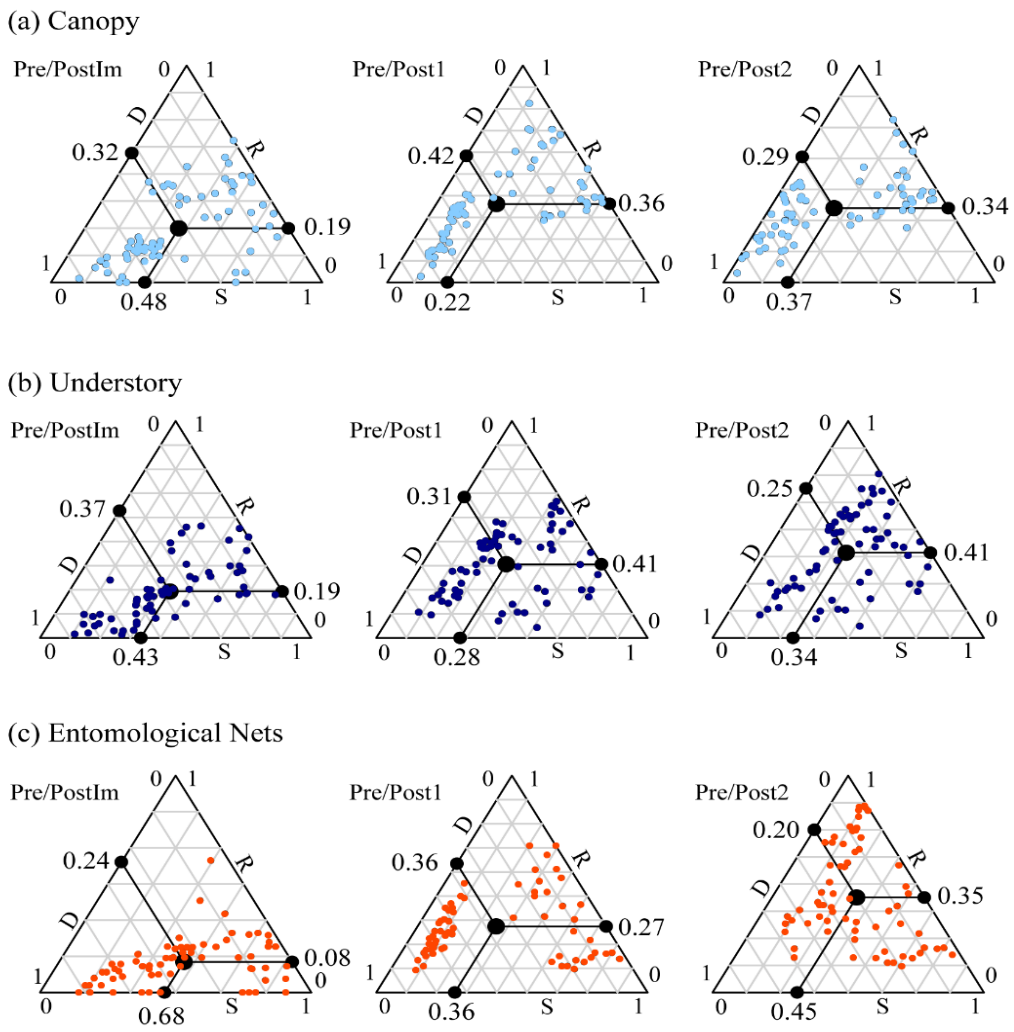

Figure 4. SDR-simplex plots generated from pairwise comparisons before (Pre, PostIm, Post1, and Post2) after the creation of the Santo Antônio dam on the Madeira River in southwestern Amazonia, Brazil. The graphs axes represent: S (similarity), D (Abundance Difference), and R (replacement). The three different sampling techniques were (**a**) canopy, (**b**) understory, and (**c**) entomological nets. The values are based on the Ruzicka dissimilarity matrix for abundance data. Each point represents a pair of sites and the large central dot in each triangle represents the centroid of the points.

4. Discussion

Our results highlight that the flooding of the Santo Antônio hydroelectric dam had a significant effect on the number of butterfly species and diversity in the area around the river. Furthermore, the composition of communities showed low resistance, with pronounced changes in species composition after disturbance, as well as low resilience, with a failure to restore taxonomic diversity levels even after two years.

In general, our results indicated that the flooding of the dam affected species richness and diversity, however only the understory sampling technique was able to capture both changes in the community. These results are supported by a previous forest disturbance study, which found that understory butterfly communities were more sensitive to environmental impacts [30]. In addition, entomological nets sampling was insufficient to detect differences.

Additionally, butterfly assemblages from areas surrounding the dam changed through time considering both occurrence and abundance, particularly in the understory. In addition, abundance data seem to be more important for more robust analyses. Changes in communities and declines in populations occur mainly due to the reduction or complete loss of breeding areas, as well as the number of host plants for feeding larvae [50,51]. Hydroelectric dams have also altered species composition in bat communities [20], suggesting that different animal communities might respond in a similar way to landscape changes.

While in some cases the environmental impacts are almost immediate, it often takes considerable time for declining populations to disappear after environmental disturbances [13]. Our results showed a low resistance of butterfly communities to the effects of flooding. Based on net collections, changes in the community occurred immediately after flooding, due to declines in species abundance. However, changes in the community tended to increase for a year after the flooding, suggesting a delayed response. Furthermore, communities seem to take a long time to recover from the impacts caused by the hydroelectric plants.

Besides richness, understory species composition seems to be the most sensitive to flooding. The understory community showed the least resistance immediately after flooding and a high replacement rate that remained over time, with no tendency to return to the original composition, presenting the low resilience of the communities in this stratum. During this relaxation time, which is a period of community restructuring after a disturbance, some populations can become locally extirpated, while other species colonize the newly formed environments [52]. This restructuring can result in the loss of relevant ecosystem functions, decreasing the ecological stability of communities [53]. Future studies should conduct long-term sampling to cover the long relaxation period [54].

While we expected communities closer to the riverbank to be more affected, there was no difference in richness or composition among sampling locations along the distance gradient. The lack of difference might be due to forest degradation caused by the construction of the hydroelectric plant, which occurred throughout the study site not just at the riverbank [3]. The destruction and degradation of the forest during the construction and operation of a hydroelectric plant probably do not follow a gradient of distance from the river [3]. Additionally, the limited data collected before the filling of the dam do not make the analysis of the temporal patterns of the community before the flood possible. Thus, the observed changes could be related to some long-term phenomenon unrelated to the dam. Understanding long-term effects requires long-term studies, and future research should begin well before dam construction to collect baseline data and also at control sites so that natural fluctuations in species densities can be documented [55].

Protocols that bring together different sampling techniques maximize the probability of species detection and are ideal to estimate richness [23], owing to differences in the detection capacities of each method [56]. However, bio-monitoring programs require simplified and efficient protocols that retrieve as much biological information as possible when analyzing smaller datasets, mainly due to limited finances [22,56,57]. Here, we compared three sampling techniques and found that using understory baited traps was more cost-effective than canopy sampling, both in terms of setting up and checking the traps. In addition, considering that the results of understory and canopy trapping indicated redundancy, we suggest that understory sampling protocols are sufficient to monitor the impacts caused by flooding from hydroelectric dams in tropical forests.

Nevertheless, the success of active sampling is directly dependent on the collector's ability [29]. Therefore, this sampling technique is often discouraged for monitoring studies, which require standardized and simultaneous sampling schemes [29]. However, with regard to costs, active sampling is usually opportunistic and is carried out between checking the traps, not adding significant time to the sampling. Furthermore, we found differences in community responses collected by nets and understory traps, which means that protocols that aggregate both sampling techniques can yield results that are more robust and are therefore a more cost-effective approach for biomonitoring studies.

In general, the environmental costs of hydroelectric dams are still underestimated or neglected and the decisions on new investments in the energy matrix mainly consider economic interests [4,13,36]. However, conservation impacts should also be considered during the planning of new dams [58]. Here, we show that filling a dam can affect butterfly communities, possibly irreversibly. We also show that optimal monitoring using understory sampling traps can be as efficient as more robust protocols while requiring less effort, which allows more effective use of time and financial resources [58].

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/d14100873/s1, Table S1: Number of species and abundance of individuals recorded before (Pre) and after (PostIm, Post1, and Post2) filling the Santo Antônio hydroelectric dam on the Madeira River in Western Amazonia, Brazil. We used three sampling techniques: canopy traps (C), understory traps (U), and entomological nets (N).

Author Contributions: Conceptualization, T.G.D.P. and D.B.R.; methodology, A.d.C.S., D.L.R.d.C., T.G.D.P. and D.B.R.; software, A.d.C.S. and D.L.R.d.C.; validation, D.B.R.; formal analysis, A.d.C.S. and D.L.R.d.C.; in-vestigation, A.d.C.S., D.L.R.d.C. and T.G.D.P.; resources, T.G.D.P. and D.B.R.; data curation, T.G.D.P.; writing—original draft preparation, A.d.C.S. and D.L.R.d.C.; writing—review and editing, B.A.A., V.A.F.N., R.A.M.F., F.T.N.P. and D.B.R.; visualization, D.B.R.; supervision, D.B.R.; project administration, T.G.D.P. and D.B.R.; funding acquisition, T.G.D.P. and D.B.R. All authors have read and agreed to the published version of the manuscript.

Funding: The A.d.C.S. was funded by CAPES (grant number 88887.595781/2020-00). The D.L.R.d.C. was funded by CAPES (grant number 88887.595781/2020-00). The B.A.A. was funded by CAPES (grant number 88887.470100/2019-00). The V.A.F.N. was funded by CNPQ (grant number 140116/2020-6). RAMF was funded by Fundect (grant number 71/700.133/2020).

Data Availability Statement: Data are available and can be requested from the authors.

Acknowledgments: We thank Santo Antonio Dam for the opportunity to collect and publish the data and the Federal University of Mato Grosso do Sul Ecology and Conservation Postgraduate Program (PPGEC) for the support. We also thank Onildo Marini Filho for the comments and suggestions in the first version of this manuscript and Augusto Rosa for the information about the sampling effort in monitoring butterfly traps.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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