



REASSEMBLY Newsletter

Reassembly of species interaction networks – Resistance, resilience and functional recovery of a rainforest ecosystem (DFG Research Unit FOR 5207)

#2, 2024

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I Project speaker's column

Nico Blüthgen, TU Darmstadt

¡Qué equipo!

In our first **Reassembly Newsletter** reflecting the first 12 months of our joint endeavour - analogous to the first stages of a forest succession when some seedlings arrive and grow into saplings - my column tried to reflect how we have overcome obstacles or challenges, and how this exercise already developed into opportunities and success stories. Year two was just as fascinating and full of new discoveries and at least as many achievements, although with relatively few new challenges and more routine. All subprojects have managed to complete most of their hard and demanding field work in the past year, have started to share exciting insights and statistical analyses from the entire chronosequence, and the first papers and conference contributions from this phase were achieved. Most saplings grew into young trees, and managed to survive even hungry caterpillar and peccari attacks or mudslides. We had to overcome a temporary gap without a scientific coordinator, but like any natural gap in a mature rainforest when large trees suddenly fall, this one has been recolonized - in this case by a pioneer tree, dropped by a far-flying bird. Edith has smoothly and skillfully taken over the coordination, and now we are back on track. Most importantly, the whole team continued to grow together, experienced by all of us regularly during personal exchanges and scientific discussions during live and online meetings, emails or other messages. Obviously, being together

in the rainforest or in the pleasant Chocó lab tightens our bounds, and enjoying these greatly improved meals in Canande...

There would be many more details or metaphors to add to this review of the year. However, for this Newsletter, I decided to hand over the column to David. Apart from Martin and me, David has been a original founder of Reassembly from the very first day. Or should I say, a world-known ant expert has been a "foundress of our large, polydomous and polygynous Reassembly colony"? Anyway, without his strong scientific work and collaborative network, without his inspiration, personal motivation and social skills, Reassembly would not have happened in this way. Now I am honoured to be his host for his two-year sabbatical on a researcher and lecturer position in my lab in Darmstadt since last summer. His office is only few steps away, so I now pass the baton to him.

An Ecuadorian perspective on Reassembly

David Donoso, EPN Quito & TU Darmstadt
On the shoulders of giants

In 1802, Humboldt arrived for the first time to Ecuador and described Ecuadorians as "strange and unique beings: they sleep peacefully surrounded by roaring volcanoes, they live poor among incomparable riches, and they become happy listening to sad music". Humboldt traveled across Ecuador, and while he was interested in countless academic matters, he is perhaps best-known for his research on the ecology of high-altitude volcanoes, a topic of great interest for the time. In his endeavors across the country and beyond, Humboldt did not travel alone, but received help from passionate Ecuadorians from the time, like Carlos de Montúfar, renown scientist, but also an independentist, and a major force in the liberation of Ecuador from Spain. Two hundred years later, as German science evolves in its sophistication, it continues its interest in the tropical study that fascinated Humboldt: biodiversity and geography. And like in Humboldt times, successful outcomes will depend upon efficacious interaction with locals.

At least three factors help Reassembly become a successful international collaborative project. First, objectives and goals are shared, clear, simple, and tractable. This is the factor Reassembly succeeds in the most Reassembly main goal (i.e., build knowledge around the recovery of tropical forests) is as simple as it gets, and all PIs and students are passionate about it. Second, a shared vision of positive outcomes is held by the top decision makers and the executors of that vision. For collaboration to be successful, both sides must view it positively. Positive attitudes make daily obstacles solvable, which in Reassembly are not few. And it just takes one conversation with Katrin (Heer and Krauth), Karin Römer, or Timo, to recognize Reassembly is loaded with positivism. Third, successful collaborations start with good relationships at the top and are maintained with focusing on sustaining partnerships between the top decision makers and those at the lower levels. While it is no secret that Nico and I have developed a good friendship over the years,

Reassembly is kept alive by the many examples of comradeships and mini collaborations born after the start of the project, between reassembly and local people in Canandé and Darmstadt, within students in the different subprojects, and among German and Ecuadorian scientists. Perhaps the best example of the materialization of these three factors is provided by the nice soundscape paper by Jörg Müller and company. A quick inspection of people in both co-author and acknowledgments lines quickly reveals the complexity of interactions with local people, Ecuadorian and non-Ecuadorian scientists, working with or not in Reassembly, all contributing generously to this simple research idea. These are good indications that Ecuadorian and German colleagues share the goal of a successful Research Unit (RU).

Reassembly is neither the first RU in Ecuador, nor the last one. In the south of Ecuador, a large group of German and Ecuadorian scientists have been active (or are active) in Ecuador for the past 25 years in projects like RESPECT (<https://www.calameo.com/accounts/7122185>). These RUs have been successful in graduating a large number of PhD students (n = 66) and are fed by long-standing cooperation with several universities UTPL, UNL, UDA and UC; and NGOs like NCI and Jocotoco operating in South Ecuador. Like us, RESPECT keeps a newsletter, the Tabebuia bulletin (https://vhrz669.hrz.uni-marburg.de/tmf_respect/) German legacy in Ecuador

Collaborating with local partners and training students do have consequences in Ecuador. Evidence of the impact of Germany in Ecuador can be measured by the number of associations formed by Ecuadorians 'after' their training or living in Germany. To my knowledge, there are three associations in Ecuador and one in Germany that together reunite about 300 Ecuadorians. One of them, the AEPEA (Asociación Ecuatoriana de Profesionales con Estudios en Alemania AEPEA) which the youngest and most active association (founded in 2019) looking to increase the interchange of people and resources between the two countries (<https://aepea-ecuador-es.alumniportal.com/quienes-somos.html>). Its counterpart in Germany, NEZLA e.V. - Verein für nachhaltige Entwicklung und Zusammenarbeit in Lateinamerika, is interested in increasing direct links between Ecuador and funding agencies (like DAAD, GIZ, and DFG) in Germany.

Going back to Germany. How does academic collaborations enrich German academy?

Besides working in great weather and eating nice mangos, working in Ecuador provides important benefits to Germans. First, traveling to remote places like Canandé, Buenaventura or Parque Nacional Podocarpus allows Germans to explore biodiversity that is inaccessible to them otherwise. Working with local experts, provides intangible benefits like reduced risks and increased speed with bureaucratic red tape. From these Ecuadorian experiences, Germans come back to their labs with important research that enriches their daily interactions at their home universities. Transferring knowledge to countries with less resources promotes balance in the world, making academia a more friendly and open place to work. In sum, conducting research in Ecuador helps increase understanding between peoples, reduces the inequalities of the research system, and provides Germans unique research opportunities, and sometimes, let's be honest, botflies, leishmania, and staph infections.

Measures of success in reassembly

As we enter the third year in Reassembly, most field work has already been done, and most datasets are finally complete. And as scientists, our more precious riches will soon start to emerge. Our work will provide us an opportunity to demonstrate the impact of our collaboration. For us in Reassembly, this does not only translate in the number of co-authorships but also translates in the amount of information the

project will produce on tropical rainforests. If Humboldt puts the Tableau Physique of the Chimborazo on the world map, the Chococoan Chronosequence of Canandé will be Reassembly's best legacy.



Figure 1: Photo of some of the members of REASSEMBLY at Casa Amalia in Quito Ecuador 2022. From left to right Connie Tremlett, Thomas Schmitt, Heike Feldhaar, Nico Blüthgen and David Donoso



Figure 2: Photo of REASSEMBLY members at the Choco Lab 2022. Starting from the back left, Mark Oliver Rödel, Eva Tamargo López, Thomas Schmitt, Sebastián Escobar, William J. Castillo, Diego Marin, Lukas Werner, Heike Feldhaar, Connie Tremlett, Ana Falconi, Nina Grella, David Donoso, Karla Neira Salamea, Arianna Tartara, Lady Condoy, Anna Rebello Landim, Bryan Tamayo, Carsten Dormann, Ugo Mendes Diniz, Nico Blüthgen, and Elis Martinelli

SP Coordination Module

Edith Villa Galaviz (new scientific coordinator), TU Darmstadt

Changes in CM

What a challenging year for CM! There was no official coordinator in the field season when CM had to repeat the P-REX, collect environmental data, and install new equipment. The new coordinator (me) started working from Mexico in April and officially in Darmstadt in June. Despite this "disturbance", CM resisted, thanks to many members that help with advice or labour, people that keep things going like Chocolab, Nico and his infinite energy, and Karen who spread her niche, taking the position when it was highly needed. It is thanks to all of you that CM could continue with its activities.

CM in the field

1. Repetition of the Perturbation-Recovery Experiment (P-REX)

CM managed to repeat the P-REX with a team headed by Karen (SP6), whom Bryan, our fantastic plot manager, highly supported. They organised a team of parabiologists and repeated the P-REX experiment in half of the plots disturbed in 2022. They measured the biomass in the plot before removal, and they did it quite detailedly. They measured the biomass of the different types of plant groups (e.g., herbs, grasses, vines), litter, and with the help of Becha, a graduate student at UpscaleR, CM can measure the recovery of seedlings. They also established a seed predation experiment where they put a known number of sunflowers seeds and counting the number of seeds removed by predators. They tested if the coating affected the seed removal and, of course, the effect of disturbance and the tendency along the chronosequence (Fig. 3). They observed a higher number of seed removal with the increase in the regeneration time. They also observed a higher variance in the removal of seeds with coating that without it. CM with the help of Arianna (SP2), who fortunately pointed out the flaw in the CM protocol, it was possible to measure decomposition by microorganisms. Arianna has been seen working in a nice paper on this and we cannot be more glad. Likewise, Nina and Ana (SP7) set a wood decomposition experiment while Santiago and Ana (SP4) assessed the seed rain. Finally CM with help from Diego, David's technician, set pitfalls to assess the recovery of the arthropod community.

Nico, Karen, and I organised the setting of an ant exclusion experiment suggested by David. The experiment aimed to test if the "ant protection" on plants against herbivores and fungus was affected by disturbance and how it changes across the chronosequence. With the help of Chocolab, Karen organized the planting of 1152 seedlings, and I, with advice from Eva (SP5), established a protocol to measure herbivory that Bryan once more carried out in the field with help of the whole Chocolab (including me). We completed two rounds of herbivory measurements last December, and I look forward to seeing the results!

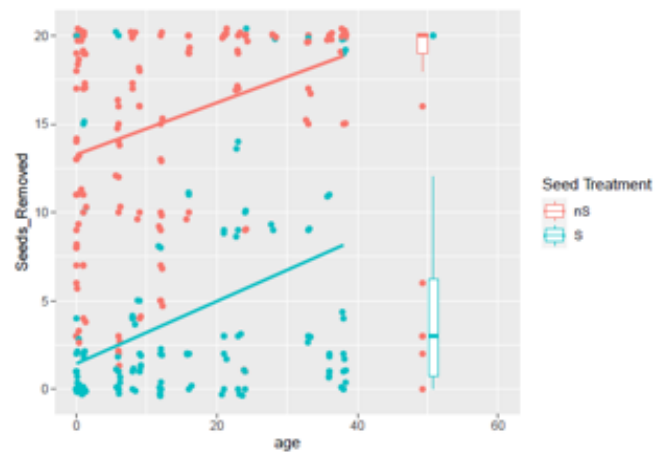


Figure 3: Number of sunflower seeds removed with coating (s) vs no coating (ns) in the P-REX experiment along the chronosequence. Boxplots on the right show the variation among the old-growth plots which are not included in the regression.

2. Baseline data

Besides establishing the P-REX, the scientific coordinator and Chocolab are in charge of collecting environmental data. We collect information on humidity, temperature of the plots, soil humidity, and soil temperature and precipitation. With the help of Felicity and Karen, we installed two rain gauges, one in Canandé and the other in Tesoro, and they have been taking precipitation measurements since June 2023. In November, Chocolab and I installed soil loggers in the P-Rex experiment to test for differences in soil humidity and temperature in recently disturbed areas, areas with one year of regeneration (P-REX 2022), and control areas. Data will be available in February 2024. However, temperature and humidity are not the only information we got from the soil. Sebastián coordinated soil sampling and sent samples to a lab in UDLA to assess the soil chemistry and composition in the Reassembly plots. Samples analysed so far showed that soil texture is not homogeneous across the Reassembly plots, with levels of lime being tentatively higher in the agriculture plots. We will happily share the soil fertility data within the first half of 2024 and in the site description paper.

Since 2022, CM has been collecting data on the humidity and temperature in the plots, and the new coordinator has continued... I wished it was just like. Collecting that data was the leading cause of distress in Chocolab. We used the same downloader equipment as in 2022 to take data from the loggers installed in the field. However, the equipment had a memory defect, and we struggled to get the data. Of course, it was not until we tried to download the data that we realised it did not work. Data was there, but there was no way to take it out. We had to return the equipment to the seller who downloaded the data and sent it to the manufacturer to translate it into "human-readable format." Unable to use the downloaders anymore, Chocolab got a computer to use in the field. Katrin, Julio (the station manager assistant since 2023), and I had Zoom sessions to learn how to download the data connecting the logger to the computer. Katrin and Julio trained the parabiologists, and we have been able to continue with data downloading. Things can go wrong in many ways, especially with equipment in places with high humidity, such as Canandé. My piece of advice is that the best backup is people, teach others, spread the knowledge. "Don't pull all your eggs in one basket"

CM in the office

When we are not organising meetings, writing emails or busy with other responsibilities, Nico and I work on some synthesis papers. Nico is working on the P-Rex synthesis paper. In his preliminary analysis, he observed that grass recovers partly after disturbance (Fig. 4), while vines and palms showed poor and no recovery, respectively. Meanwhile, I am slowly working on a synthesis of the turnover of species and comparing across taxonomic groups. I classified species into the pioneers, intermediate, and climax using null models based on species abundance along the chronosequence. It is interesting to see how the different groups differ in their pioneers and climax species percentages. For example, the proportion of pioneers species is higher in mobile groups like birds than in sessile species, e.g., trees or seedlings (Fig. 5).

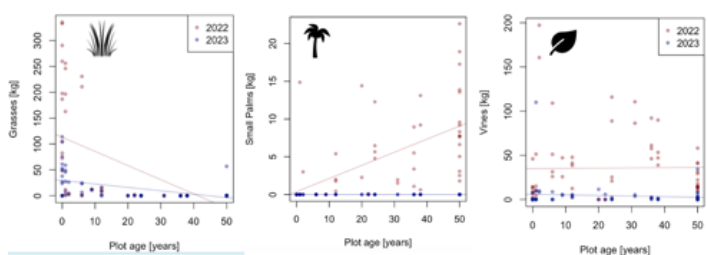


Figure 4: Biomass (kg) of vegetation removed in the P-REX experiment in 2022 (red) vs one year later (2023; blue) of some groups of plants across the chronosequence. From left to right: grasses, palms and vines

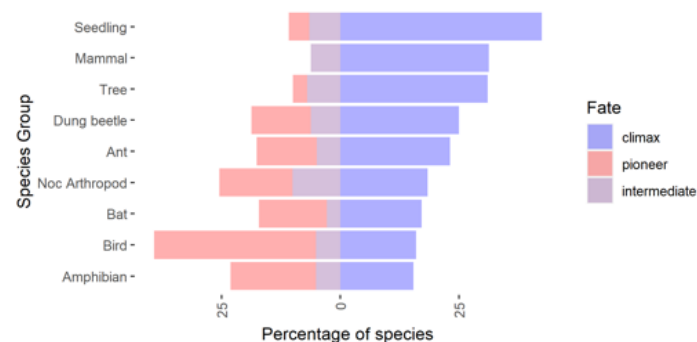


Figure 5: Percentage of species classified into pioneers (red), intermediate (light purple) and climax (red) for different groups of species studied in Reassembly. The groups of species included were: seedlings, mammals, trees, dung beetles, ants, nocturnal arthropods (Noc Arthropod), bats, birds and amphibians. Bar are arranged in a mirror way with the percentage of pioneers and intermediate on the left and the percentage of climax on the right of zero. It both cases the percentages are positive percentages. Fate refers to the fate or category established according the null model

Synthesis workshop

Last September we had our synthesis workshop in Bad Homburg during the meetings, leaders of the synthesis papers presented their proposal and in some cases preliminary results (including Nico and I). We had a very productive discussion during the workshop, authors got some great ideas from Reassembly members and now synthesis paper are moving forward. However, the main achievement of the meeting was to ease any concerns about synthesis paper affecting individual papers showing a great collaboration spirit within the Research Unit.

CM's collaborators

There are always more ideas than actual human power. Fortunately, we had three great collaborators this year. Dr. Felicity Newell has been collaborating with us on multiple projects. She has been working on spatial information and environmental data of the Reassembly plots and helping select new plots for the second phase. In September-October, we had Ronja Nusser, a master's student at the University of Wuerzburg, who worked together with SP7. She measured the canopy and microclimate in the plots of Reassembly. In November, we had Tim Lehman, a master's student supervised by Martin Ehbrecht (University of Göttingen), who scanned most of the Reassembly plots using the method Lidar, and thanks to them, we will have great measurements of the canopy of the plots, among other measurements. Ronja and Tim have never been to Canandé or the tropics before, but they did a good job. Being successful was highly dependent on maintaining communication with their supervisors and having a parabiologist to guide them in the field and help them solve unexpected situations.

In challenging times, build a team and carry on

Changes always cause turbulence. Fortunately, the Reassembly Research unit members have been very patient. Thank you all. In the last newsletter, Connie (the previous coordinator) highlighted the importance of people in Reassembly. I couldn't agree more. Starting as a new coordinator in the middle of the project has been challenging. I have done the job thanks to all the people in Canandé and Darmstadt. The Choco lab team (Bryan, Katrin, Julio and all parabiologist that support all SPs) has been helpful and supportive. Thanks to them, I learned that building a good team is essential to have the job done. And that what makes a good leader is not having all the answers but the ability to make people feel comfortable enough to express their ideas. A team is, after all, a group of people working together to achieve a goal.

A especial dedication to Tarsilo

This year has been especially tough for Tarsilo (Reassembly's mule). He got sick and after that got an infection on his foot. He has been on sick leave for the last six months. Fortunately, Tarsilo is recovering and enjoying being under the care of Tio Gordon and the medical care of "Ojito" (a Jocotoco park guard). He likes to be in Tio Gordo's pasture so much that when Tio Gordo took Tarsilo to another pasture, he returned to Tio Gordo's pasture, worrying everybody in Chocob. May Tarsilo have a 2024 year filled with health and happiness.

Coordination Module

Sebastián Escobar, Universidad de Las Américas

What everyone should know about my work

As part of the the Coordination Module (CM), I am mainly responsible for obtaining data on forest structure and tree diversity. I am also in charge of preparing a genetic barcode library for all the tree species found within our survey. Additionally, I handle all permits required for students and researchers to perform their field work and sampling within Ecuador. I am enrolled at Universidad de Las Américas (UDLA) as a postdoc researcher and work directly with María José Endara, an expert in tropical ecology and herbivory. I have also collaborated directly with Juan Guevara who has been actively involved in tree identification at the herbarium. During this year I have been coordinating activities with David Donoso, Felicity Newell, Edith Villa, and Nico Blüthgen, with whom we are writing a field description paper of the project. The parabiologists Fredy Cedeño, Jerson Loor, and Franklin Quiroz were key collaborators and contributed substantially in the finalization of the tree survey.

Activities

1. Forest structure and tree inventory

During the first semester of 2023, the four plots at Casa Rosero that remained from last year were tagged and their diameter at breast height (DBH) and height measured. The tags and nails of around 20 plots were also changed for aluminium ones, which will remain attached to tree stems allowing their identification in the future. This year we surveyed 30 plots, finishing the 62 plots that are part of Reassembly. Field work during this second year was a little less challenging because we already got used to the rhythm of this activity and every member of the team knew their role. Also, the 12 active cacao and pasture plots were surveyed within this year, reducing the time spent in the field because we were able to finish two or three of these plots per day. In contrast, plots in old-growth forest took between three to five days to finish.

This year, 2792 trees were surveyed and measured, giving a total of 7546 trees within the 62 plots. From these, around 90% of individuals have been identified up to species level. Thus, additional work in the herbarium is still required to complete the identification of all samples collected. Nevertheless, unidentified individuals were classified as morphospecies allowing the obtention of alpha diversity indexes per plot such as species richness. In total, we collected around 120 wood or bark samples from trees that did not present leaves during the survey or that were too high to reach them. The idea is to identify the species of these trees using genetic barcodes. A first step to achieve this goal is generating a successful protocol of DNA extraction from wood samples. This activity represents the undergrad thesis of the UDLA's undergrad student Daniela Fierro, which is close to be completed. A second undergrad student will develop a thesis by barcoding the rest of the wood samples during the first semester of 2024. This will increase the amount of individuals fully identified within our survey, providing more accurate estimates of species diversity.

2. Site description paper

During the last trimester of 2023, CM started writing a paper led by me that describes the study site where Reassembly takes place. This paper aims to provide the theoretical background and the design of the chronosequence implemented in the project. It describes the spatial

characteristics of the 62 plots such as their location, distances between them, elevation and its lack of correlation with time of regeneration time (Fig. 6), among others. The paper will also include abiotic baseline data from the plots such as temperature, canopy cover, humidity, soil composition, and landscape composition derived from satellite data. These data can be included as covariables in the linear mixed models implemented by students and researchers within the project.

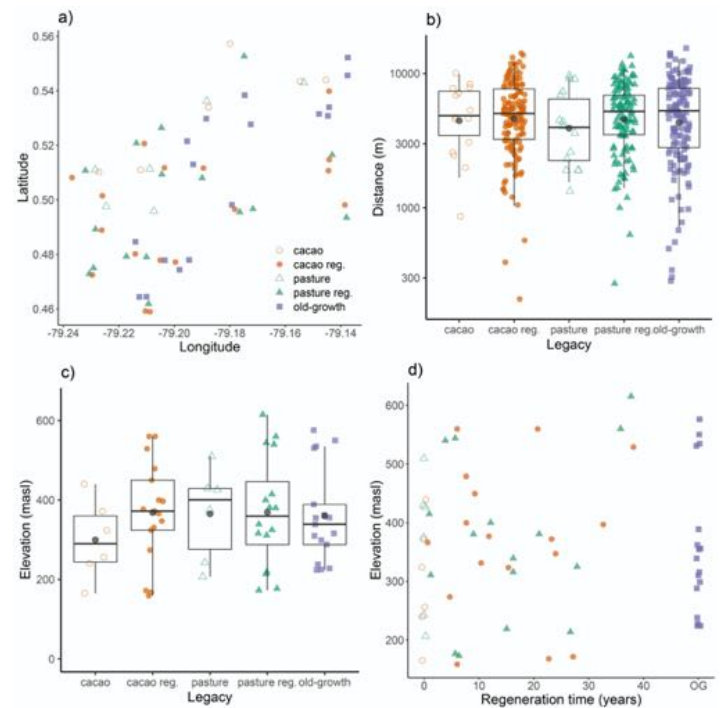


Figure 6: Plot spatial characteristics. a) Location of the 62 study plots at the Canandé and Tesoro Escondido reserves in the lowland rainforests of northwestern Ecuador. b) Distances between plots within each land-use legacy type. The y-axis is log-transformed to facilitate the visualization of low values. c) Elevational distribution of each land-use legacy type. d) Elevation is not correlated with regeneration time in cacao and pasture active and regenerating plots. Old-growth forest (OG) plots were not included in the analyses because their time without human intervention is unknown. Dark circles in all boxplots represent mean values.

In addition, we present a case study on how forest structure and tree diversity increase with regeneration time along the chronosequence in former cacao plantations and pastures (Fig. 7). Preliminary analysis include basal area as the response variable to explain forest structure, however this will be changed for above ground biomass in the final version. We used linear mixed models with basal area and tree species richness as response variables, square root transformed regeneration time, elevation, and land-use legacy (cacao plantation or pasture) as fixed effects, and whether the plots are PREX as random effects. Old-growth forests were not included in the models because there is no certainty of the time these forests have remained without human disturbance. We determined that the best models included regeneration time and previous land-use legacy (cacao and pasture). We estimated that cacao plots would take 65 years to recover their basal area to the levels of old-growth forests while pastures would take 70 years. In terms of species richness, cacao plots would take 39 years and pastures 41 years to recover. We obtained negative resistance values for basal area and species richness because we reduced them to zero in active cacao and pasture plots (Fig. 8). The logic behind this is that we are studying natural regeneration and therefore



we did not want to include trees that were not naturally dispersed but instead were left standing when the forest was cut down. Resistance was consistently higher for cacao than for pasture plots. Regarding resilience, it was lower for basal area than for species richness which is consistent with the estimates for total recovery.

4. Research permits

An important activity managed by CM is the obtaining of all the necessary permits required by students and researchers to collect and transport their samples. This year, 19 mobilization permits have been obtained and 18 export permits were processed, three of them being CITES export permits.

Plans for 2024

The site description paper will be submitted at the beginning of 2024. The identification of all plant samples will be finished during the first trimester of the following year. This information will be useful to complete a couple of papers that will be written during 2024. The first paper is a synthesis that will look to unravel patterns of phylogenetic diversity along the chronosequence in plants and animals and how they interact between them. The second paper looks to understand changes in alpha and beta diversity of tree communities along the chronosequence of forest regeneration.

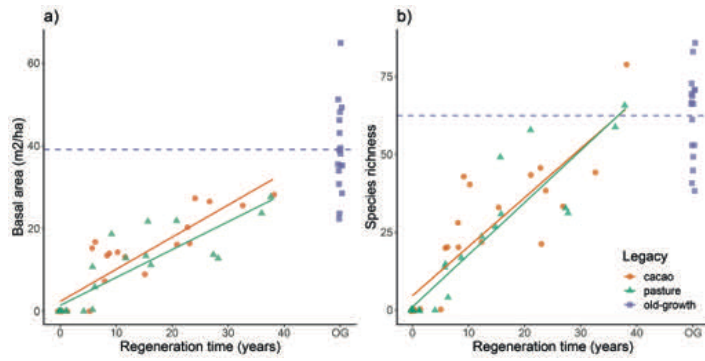


Figure 7: a) Basal area and b) tree species richness increase with regeneration time in cacao and pasture plots. Horizontal dashed lines show the mean value of the Y axis for old-growth forests (OG).

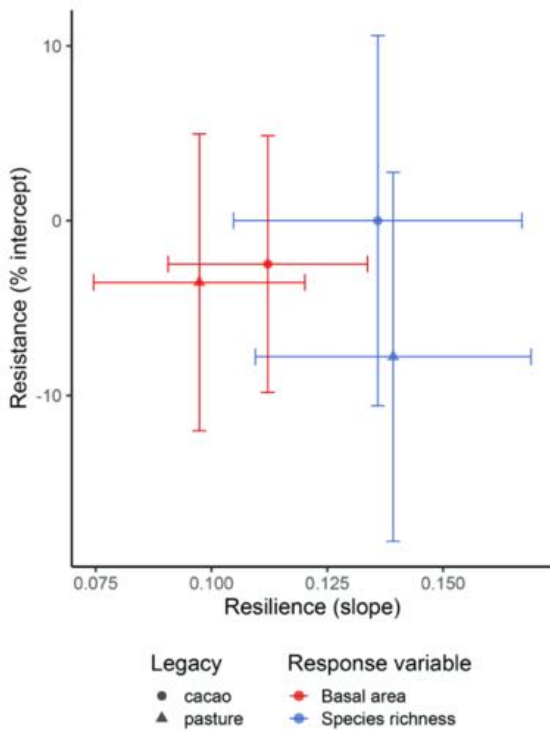


Figure 8: Recovery dynamics of active and regenerating cacao and pasture plots. Lines represent 95% CIs.

3. Genetic barcode library

The construction of the genetic barcode library already started. So far, we have performed DNA extraction of more than 1000 plant samples corresponding to the 728 species and morphospecies identified so far. DNA has been already quantified and diluted to a similar concentration, which allows to obtain similar amounts of PCR products. PCR of the ITS2 barcode are being currently performed in 96-well plates and we expect to send these samples for sequencing at Macrogen in Korea up to March 2024.

SP I: Theory and modelling

Timo Metz, TU Darmstadt

Who we are and what we do



Figure 9: Rare observation of a theoretician in the wild.

SP I is the theoretical subproject of REASSEMBLY, seeking for general patterns and rules in the assembly of ecological networks. We are interested in developing theoretical models that help us understand which network assembly patterns are to be expected in the field data, and why they make sense. It consists of two PIs and two PhD students. The PIs are Barbara Drossel, a theoretical physicist, and Carsten Dormann, an ecologist with a strong focus on statistical analysis. My PhD student colleague is William Castillo, who works on the statistical analysis of ecological networks in Carsten Dormann's group. I, Timo Metz, am a physicist and biologist, combining these two fields of studies in Barbara Drossel's research group, to model the assembly of ecological networks. I also recently joined the research group of our project speaker Nico Blüthgen, who is also based in Darmstadt, in order to facilitate some of the synthesis work of REASSEMBLY and refine the theoretical models used in our subproject. For the development of models and the synthesis projects, I work together with all the various subprojects. This makes my work very interesting, as I get to learn many things about the various taxa studied in REASSEMBLY and have the privilege to discuss with all the brilliant REASSEMBLY members about their amazing findings.

Field impressions

Well – who would have guessed the first newsletter subheader of the theoretician to be *field impressions*? Surprise ! But it is true. This year, I went to visit the field station in Reserva Canandé, to accompany and support some of the other PhD students with their field work, and even doing some field work myself. Here are some proof pictures:



Figure 10: Me with our project mule Tarsillo on the way to Casa del Medio.

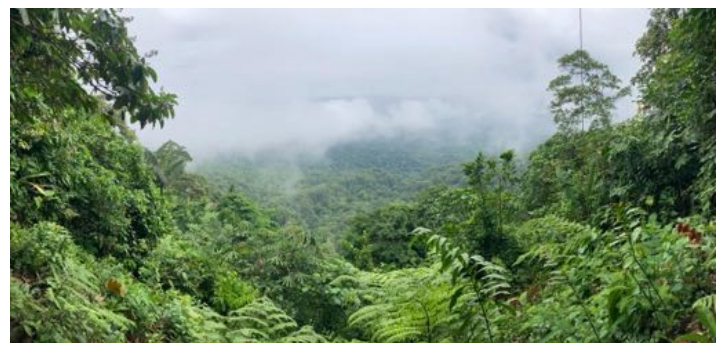


Figure 11: Beautiful view on parts of the reserve.

Long story short, I had a very amazing time. During my stay, I went to the field with some of our PhD students and also spent many days together with our new project member Felicity Newell. I got to know how my fellow PhD students collect some of the data, and experienced myself the labour intensive and physically exhausting backstory behind the data points that I analyze at home. Also, I got to see many hurdles that are faced on the way, and experienced the creativity that is necessary to obtain good data in the challenging circumstances of the Chocó. The ever-prevailing humidity, lots of rain, deep mud and tiredness make the data sampling difficult. However, I fortunately also got to experience the upsides of the field, such as the generally amazing landscape of the Chocó, the happiness of contributing to good field data and the invaluable friendliness and friendship of REASSEMBLY co-workers and locals alike. I think my time in Ecuador certainly provided me with unforgettable memories, but also contributed to me understanding better where the data that I use comes from and how it is obtained. This brings me also to my next topic.



Why should a theoretician go to the field

One could certainly argue, why should a theoretician go to the field at all. It costs money, time and – when flying to Ecuador – also contributes to climate change. So only “fun and nice memories” is maybe not good enough of a reason. Quite generally, as a theoretician I try to identify general patterns and develop ideas on which rules could govern the dynamics of a certain system – in this case species interaction networks in tropical rainforests. While this sounds rather abstract, I give you an example: In REASSEMBLY, we are interested in how species interaction networks “reassemble” over time. That is, what is the structure of the interaction networks at different stages of rainforest recovery. A theory can help us to understand why a certain pattern we observe emerges. For example, we could explore whether the network patterns we observe in forests become more stable with time of recovery – or maybe also not. Furthermore, we could also identify if the network patterns are purely a secondary effect of the development of other ecosystem properties, such as the abundance of species and the species richness. Models are a useful tool of a theoretician that can also help us first to generate a hypothesis and understand why a pattern that we observe makes sense. However, as a theoretician one of the jobs we have is to “idealize” or to “abstract” the complex reality we face, so the problem becomes simple enough to understand it and describe it. In order to do that, we must know the object of study very well – otherwise it is not very easy to know which assumptions we can make with a good conscience. This includes getting to know the study object “live”, because otherwise it is very difficult to estimate which assumption is biologically intuitive, and which is not. And, next to the purely scientific purpose of going to the field, I think ecology is a field of science that needs both – theory and empiry. Therefore, it also makes sense that empirical and theoretical scientists work closely together. That can include talking at conferences, workshops and in the lab, but it also includes the occasional visit of the theory guy in the field – putting on rubber boots and helping to get some nice data.

Back to theory: Keep the modelling going

While still daydreaming about my time in Reserva Canandé there is also some modelling left to do. This year, there were two major developments. The model for the assembly of mutualistic networks (see last year’s newsletter) has undergone further refinement. We included a “finite species pool” from which we assemble the network. Thereby, we allow to study how predictable the assembly of networks is, and to which extend the assembly is influenced by varying ecosystem and assembly properties, such as the species pool size and the immigration rate. This work culminated in a paper, which is now at the stage of being submitted. Second, I have been supervising multiple student thesis adapting the general network assembly model to now include antagonistic interactions, such as between plants and herbivores, where one guild profits from the interaction while the other one suffers. This work is also of some interest for other subprojects that work with these antagonistic interactions. A major difficulty was to obtain a specialized network, which is commonly observed empirically for these types of networks. However, in the end we were successful in obtaining a first working model, which we can now use for further studies.

Time for synthesis: Putting the pieces together

The year 2023 has also been the year of obtaining the first data. Since REASSEMBLY is a research group consisting of many researchers with various taxa being studied, it is a natural goal to combine the data and look for general patterns and get overarching insights. The synthesis project I am leading follows the “Resistance-Resilience framework”

(mostly going by its easy-to-remember abbreviation “Resi-Resi” ;)). Resistance and resilience are two different stability measures. Resistance refers to the fraction of a measure (such as species richness, or species community composition) that is left after clearance with respect to a primary forest. Resilience refers to the rate of recovery back to the level of a primary forest. My work includes calculating the resistance and the resilience of various taxa studied in REASSEMBLY (see other PhD newsletters for more info !) and also creating a literature research that aims at comparing the results we obtain in REASSEMBLY with results obtained with other studies. Optimally, we should find some commons and differences between taxa – for example due to differences in mobility and sensibility to deforestation. Also, we should find commons and differences between studies – for example due to differences in forest cover in the individual study areas. Due to the ongoing process of the work, I am not sharing any results here yet – so stay tuned for next year’s newsletter :).

Outlook

Next year, I will hopefully finish the “Resi-Resi” analysis, that is expected to culminate in a nice paper. For this, I need to finish some remaining analysis and discuss with the project members that provided the data on how to best interpret everything. In March 2024, a workshop is planned in Quito, which I would like to attend. Afterwards, I would like to visit Reserva Canandé again for some time, in order to help with some of the field work and hopefully make further unforgettable memories.

SP 1 - Agent-based Model to identify logging risks of *Ateles fusciceps fusciceps*

William J. Castillo & Malika Gottstein
Albert-Ludwigs-Universität Freiburg

Who we are

We, William Castillo (background in physics) and Malika Gottstein (background in primate ecology), want to identify the logging risks for brown-headed spider monkeys (*Ateles fusciceps fusciceps*) in the Ecuadorian Chocó. We are working together with Citlalli Morelos-Juárez (Fundación Tesoro Escondido) and Felicity Newell (Universität Bern).

Motivation

The brown-headed spider monkey is one of three primate species of the Chocó (Figure 12). The species was listed as one of the 25 most endangered primates worldwide [7] and is classified as endangered (IUCN category EN). The subspecies *A. f. fusciceps* is endemic to north-western Ecuador and was reduced to a population size of a few hundred individuals [2, 12].



Figure 12: Male *Ateles fusciceps fusciceps* in Reserva Tesoro Escondido.

Brown-headed spider monkeys are particularly susceptible to habitat changes due to their ecological requirements and slow life history that are associated with a low tolerance for habitat degradation (Figure 13) [11].

In the province of Esmeraldas, in the north west of Ecuador, many of the spider monkeys' feeding trees are also targeted as timber species [8]. Under current extraction protocols, many important feeding trees are significantly impacted and some are predicted to disappear [8].

Objectives

The aim of this project is to develop an Agent based model (ABM) for brown-headed spider monkeys, using field data collected in Tesoro Escondido and data available in the literature. We want to use the ABM to answer the following questions:

- How will spider monkey populations fare under the current logging protocol and under different scenarios?
- For the subspecies to survive, how much would the rate of habitat destruction need to decrease and/or how much of the degraded forest need to be restored?



Figure 13: *A. f. fusciceps* habitat around Tesoro Escondido.

Finally, we want to be able to give recommendations for public policies related to the conservation of brown-headed spider monkeys in the Ecuadorian Chocó based on the results of the simulations.

Method

An Agent based model is a mathematical representation (simulation) of the actions and interactions of autonomous agents (individuals or collective entities) with their environment. It allows us understand the mechanisms that governs the system under study [4].

Each simulated agent (*Ateles fusciceps fusciceps*) has an energy level between 0 and 2000 kcal. Its total energy expenditure per day (TEE) is described by eqn 1 [5]:

$$TEE = 86 \cdot \text{weight}^{0.792}, \quad (1)$$

which also takes into account the energy loss associated with resting, although this is not explicitly represented in the model.

When an agent's energy level drops below 1040 kcal, it will go "hungry" It will then move around, looking for food. In the wild, spider monkeys have been observed to consume approximately 1 to 2.4 kg of fruit per day [3]. The nutritional value of the fruit in Tesoro Escondido suggests that 1 kg is equivalent to 1040 kcal. 2.4 kg of fruits would then have an estimated value of 2000 kcal.

The agents can be male or female and are divided into two categories according to their age: juveniles from 0 to 8 years of age and adults from 8 to 24 years of age. When female spider monkeys reach adulthood, they are in fertile mode, with a birth interval of about 4 years between each birth [10].

The environment in which the agents will interact is based on satellite imagery analysis of northwestern Ecuador (Figure 14). The total study area is 5872 km², of which 2172 km² is protected forest and 3700 km² is unprotected forest considered suitable for the agents [9]. Two layers of information are used to create the digital representation of the landscape. In the first layer, each pixel of resolution represents an environmental patch of 30 × 30 m². The second layer represents the percentage of fruiting trees threatened by the timber industry in each patch.

Each time step in the simulation represents one day. The age of the spider monkeys then increases by one day per time step. Agents die either by old age (more than 24 years old) or by starvation when their energy level falls below 0.

Outlook

The dynamic response of the agent population will be tested under several scenarios related with the aims mentioned previously. Inspired by the economic field we will start with three scenarios related with the logging intensity:

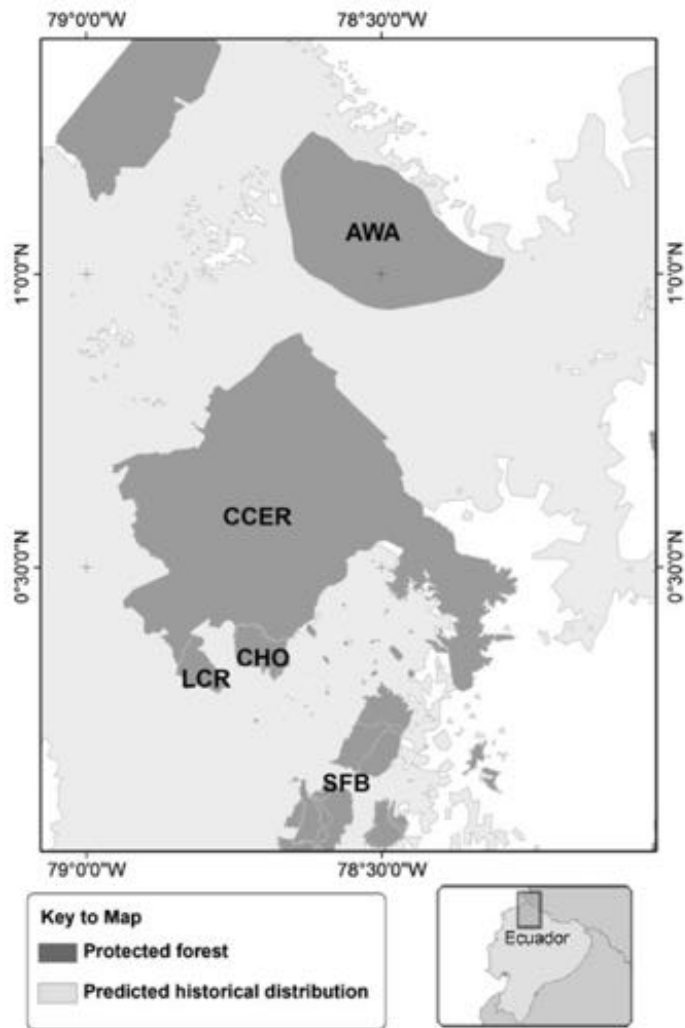


Figure 14: Map showing the study area with zones of potential historical distribution of *Ateles fusciceps fusciceps* and existing protected areas. AWA = Awa Indigenous Reserve; CCER = Cotacachi-Cayapas Ecological Reserve; LCR = Los Cedros Reserve; CHO = Chontal Protected Reserve. SFB refers to the Southern Forest Block including protected forests of Maquipucuna, Mindo, Cambugan, Deule, and Pampolona [9].

- **Worst-case scenario:** The logging activity clears the protected and unprotected areas (Figure 14) at a rate of $-197,600$ ha per year [1].
- **Business-as-usual scenario:** The logging industry follows the "Sustainable Forest Management Standards" established by the Ministry of Environment, Water and Ecological Transition of Ecuador [6].
- **Best-case scenario:** There is no longer logging activity in the areas of unprotected forest considered suitable for spider monkeys.

After analysing the results of the above scenarios, we can modify the parameters and aspects of the simulation. Among several cases, we can study the consequences of deforestation at a higher rate than recommended by the Ecuadorian government, as well as the hypothetical case of the disappearance of the protected areas and the time when *A. f. fusciceps* becomes extinct.

Over the period of the simulations, we expect an inversely proportional relationship between the population size of *A. f. fusciceps* (total

number of agents) and logging intensity. As shown in Figure (15), we expect the population size to decrease as logging begins. Similarly, as logging intensity decreases, we expect the number of agents to increase and vice versa.

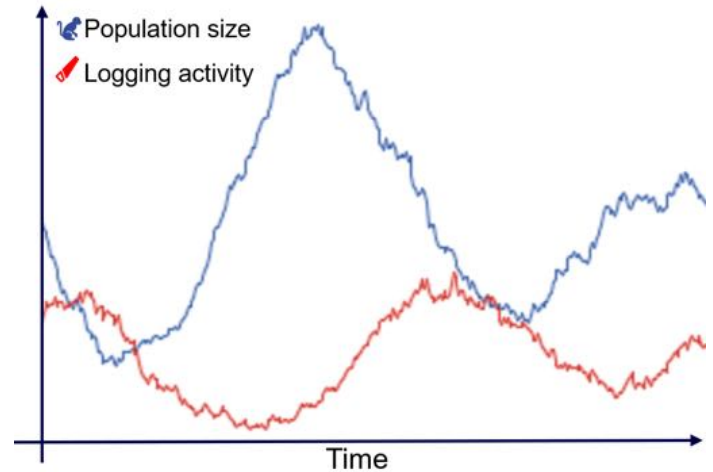


Figure 15: Expected response of the population size of *Ateles fusciceps fusciceps* to the logging activity in the north west of Ecuador.

In these simulations, we expect to find the parameters that will improve the protection of the ecosystem and allow the population of *A. f. fusciceps* to increase.

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SP 2: Leaf-litter arthropod community and decomposition processes on the forest floor

Arianna Tartara, TU Darmstadt

Recap

The year 2023 brought about a significant shift in expectations and research focus, although some aspects mirrored the previous year. I redirected attention toward understanding the decomposition processes influencing leaf-litter decay and the arthropod community in the forest floor along the chronosequence. Delays in export permits and challenges in shipping CITES-listed samples hindered the analysis of frogs' skin, resulting in a frustrating delay in the alkaloids-related aspect of the project.

As you may read in last year's edition of the newsletter, regrettably, data from the 2022 sampling campaign could only be partially utilized. The traditional leaf-litter samples (1 m² of leaf-litter collected in every plot) and the litterbags collected in the control treatments of the PREX were secured. However, arthropods' data and decomposition rates from the litterbag experiment in the disturbance treatments had to be discarded due to errors caused by mudslides. From these selected safe samples, I achieved two main objectives: 1) calculated decomposition rates in every plot, confirming that the process follows a first-order decay rate (log scale), and 2) identified the arthropods comprising the leaf-litter community of size < 0.5 cm in each plot by extracting the samples on Berlese funnels. I morphologically identified the arthropods, and I am currently awaiting barcoding results.

With the advent of 2023, the research focus shifted slightly as I delved deeper into the decomposition processes along the chronosequence. Consequently, I decided to repeat the experiment with a twist, as described in the following paragraph.

New Method

This year's sampling campaign was (once again!) a six-month-long adventure in Canandé, resulting in three different datasets: 1) new leaf-litter decomposition data within the PREX, 2) dry weight data of leaf-litter endemic of each plot after one year from 2022's disturbance, thanks to the PREX team, and 3) large leaf-litter arthropod community data, in collaboration with David Donoso as part of CM.

1. I designed a new (almost-) full-factorial decomposition experiment, building on the information from the previous year's sampling campaign that decomposition follows a log trend. The 2023 experiment involved the sequential replacement of the samples, encompassing both litterbags and teabags to determine whether to grant arthropods access to the leaf-litter. It was placed again on the four PREX treatments of all 32 plots, in the old (2022) and new (2023) disturbance, and finally above-ground and below-ground. In this newsletter, I will focus only on this first experiment, since it was the one that involved only myself (as well as a good load of manual work...).
2. In collaboration with the coordination module (CM), the leaf-litter's dry weight endemic to each plot was measured. I could compare this data with my own very same measurements from 2022 and estimate the change in leaf-litter productivity after one year from disturbance.
3. In collaboration with CM (specifically David Donoso), pitfall traps were placed in each plot in duplicates, providing information on the community of large leaf-litter arthropods in each plot.

Result

Decomposition rate constants (k) were calculated with the negative exponential model:

$$\frac{DW_t}{DW_0} = e^{(-kt)},$$

where DW_t/DW_0 is the ratio of dry weight remaining after time t [1]. Figure 16 shows the trends of decomposition rate constants for litterbags and teabags (above and below ground) in the four treatments of the 32 PREX plots along the chronosequence.

A linear mixed-effects model (LMM) was employed to investigate the impact of multiple factors on the decomposition rates of the litterbags, the teabags above ground and the teabags below ground, respectively.

The analysis considered in each independent treatment the fixed effects of the number of days passed after disturbance, the square root of the canopy closure, elevation, the interaction between legacy and square root of the forest age and the random effects of the Plot ID and collection round.

First, for all the samples the time passed from the disturbance in the control treatments did not influence decomposition rates ($p > 0.1$), indicating no temporal variations in the time frame of the experiment. This consisted of a positive confirmation that no extreme unexpected environmental condition affected the samples between collection rounds.

The presence of a fence and disturbance exhibited significant effects for the three types of samples litterbags, teabags above and teabags below ground, hence the decision to dwell deeper into the effect of each treatment.

With regards to the litterbags, legacy showed a significant impact ($F = 4.413$, $df = 1$, $p = 0.048$) in the control treatment and the age proved to have an effect in the fenced-control ($F = 5.097$, $df = 1$, $p = 0.354$) treatment. No variables currently included in the model could explain the trends in decomposition rates in the disturbance treatments.

Moving on to the teabags placed above ground, age showed to have an impact in the control ($F = 4.349$, $df = 1$, $p = 0.050$) and fenced-control ($F = 4.477$, $df = 1$, $p = 0.0469$) treatments. Elevation ($F = 3.686$, $df = 1$, $p = 0.069$) and the interaction between age and legacy ($F = 3.157$, $df = 1$, $p = 0.090$) proved to have marginal effects on the disturbance treatment, yet no variable showed any significant effect on the fenced-disturbance treatment.

Finally, no effects were observed from the variables included in the model so far to explain the decomposition rates of the teabags positioned below ground. I hypothesise that the soil data that will soon be made available by CM will prove interesting for the model.

Next Steps

In terms of future outlooks, I have the following tasks list to follow:

- Once I receive the barcodes for arthropods from 2022's samples, I will use the data for: a) Network analysis with the frog community, b) Investigating how the arthropods' community changes along the chronosequence in a community analysis model.
- Follow up writing on the decomposition data, incorporating soil parameters (chemical composition, conductivity, clay content, pH, etc.) and GIS data into the model, pending their availability.
- Analyse alkaloids on the frogs' skin, although I've grown doubtful due to the exporting issues experienced thus far.
- Identify arthropods from 2023's litterbags samples to assess the recolonization potential of the arthropod community after the disturbance.



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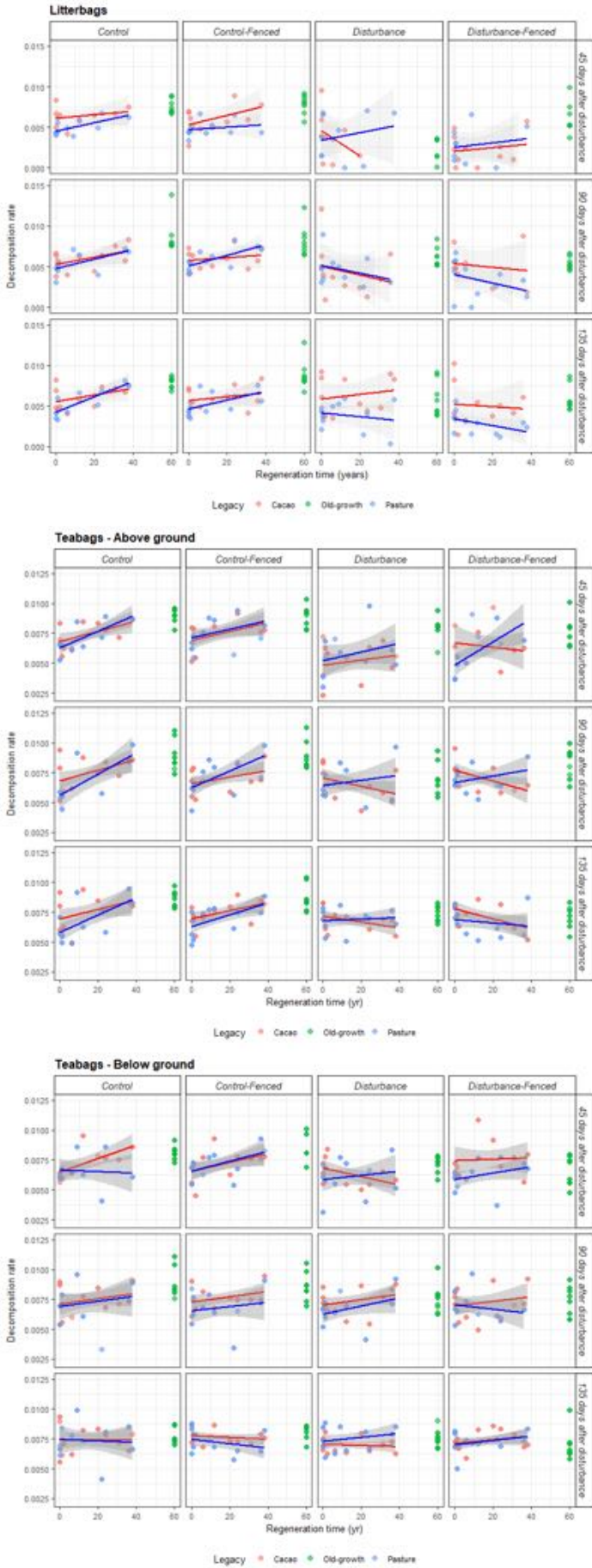


Figure 16: Decomposition rates calculated for litterbags, above-ground teabags and below-ground teabags along the chronosequence.

SP 2: Food webs and alkaloid defenses - frogs and litter fauna

Karla Neira Salamea MfN/HU, Berlin – UDLA, Quito

What everyone should know about my work

SP2 is dedicated to understanding the predator-prey dynamics between frogs and the leaf-litter fauna. Leading this effort, Arianna Tartara and Michael Heethoff focus on leaf-litter arthropod communities, with a particular emphasis on mites—a key component of the diet of poisonous frogs. Simultaneously, Karla and Mark-Oliver Rödel are engaged in comprehending the dynamics of leaf-litter frog communities and the interactions with soil arthropods that constitute their dietary sources. Our team's prowess is further amplified by the contributions of our primary collaborators, David Donoso and Ralph Saporito. David is an expert in neotropical entomology, while Ralph specializes in chemical ecology, focusing on animals that sequester defenses from dietary sources. Finally, Leo de la Cruz, my great friend and parabiologist, was essential to carry out all my fieldwork.

Now, more than ever, I believe it is crucial to understand the local processes contributing to the decline of amphibians. A study published this year underscores amphibians as the most threatened category among vertebrates, particularly facing significant challenges in the Neotropics, where the situation is most severe [3]. Notably, timber and agriculture stand out as two key factors promoting this decline [3]. These are precisely the strongest threats that have impacted the Ecuadorian Chocó [6]. The comprehension of local processes becomes paramount for implementing effective conservation measures.



Figure 17: From left to right, Karla, Leo, and Arianna performing the stomach flushing of a frog. Photo: Javier Aznar González de Rueda

Leaf-litter frogs emerge as an exceptional model system, representing over fifty percent of the amphibians in the Chocó Tropical Rainforest in Ecuador [5]. Their diverse life histories make their study captivating, showcasing a variety of morphologies, behaviors, ecological traits, and dietary preferences. This diversity offers valuable insights into the factors influencing their survival in altered habitats and their ability to recolonize degraded areas [2], as well as the reorganization of their ecological networks. My objective is to contribute to a deeper comprehension of the resilience and adaptation of anuran communities in recovering environments. By exploring the predator-prey dynamics within leaf-litter

organisms, this study aims to understand the mechanisms driving recovery and adaptation in these communities, providing valuable insights for effective conservation strategies amidst ongoing environmental changes.

Field impressions

This year, we completed the sampling of all 38 plots, with three repetitions each, both at night and during the day. The goal was to identify all leaf-litter frog species with known different activity times. Additionally, we aimed to have repetitions to ensure a substantial sample size. We continued with the same methodology as last year. We would go to the plot, actively search for leaf-litter frogs, capture them, perform a stomach flushing to obtain their stomach content, filter this content correctly, and store it. We identified the frog's species, age class, and sex whenever possible, took morphometric measurements, and, in the case of dendrobatid poison frogs we proceeded to take a sample of alkaloids. Ultimately, we released the frogs unharmed.

In 2023, we had the pleasure of hosting several members from Rödel's lab who joined us in the field. Having colleagues accompany you to the forest is quite special; it not only makes the experience more enjoyable but also allows for numerous natural history observations. This year, we published two articles based on observations and side projects during my colleagues' visit to Canandé. MO led an article on auto-haemorrhage in snakes that arose from an observation we made of the *Trachyboa boulengeri*, noticing that its mouth and eyes filled with blood when handling it [4]. We also published an article on predation events by snakes observed by my colleagues during their visit to Canandé [1], and there are more articles to come... I have to highlight the work of Sarah Bock, a master's student studying the microhabitat of frogs, and in addition to that, she and the parabiologist Holger Vélez, discovered a new species of salamander for science—an extraordinary animal that is currently being described.

Fieldwork was quite challenging—working when everyone else is asleep and being obligated to stay awake when everyone else is awake is certainly tough. However, the enchantments that the night brings in the forest are incredible. I believe there wasn't a single night without witnessing something spectacular. Every night, there were snakes, including the one I waited an entire year for, *Botrichis schlegelii*—I finally saw it on the last night of the second field season. Our experiences with the presence of felines were truly unique—from encountering an armadillo freshly attacked by a puma or jaguar, only to discover upon our return that its predator had already taken it away; checking a colleague's camera trap and finding that the photo just before mine captured the puma; to observing the tracks of the puma circling the place where we had been sitting for more than an hour processing the frogs. And, of course, gradually getting to know the calls of the frogs and witnessing the incredible diversity of these amphibians is amazing. My favourites are still the *Pristimantis*—not the most popular or iconic frogs, but understanding the vast diversity within the same genus is truly fascinating

Results

During our fieldwork, we encountered a total of 944 frogs during the samplings, belonging to seven different families. These include Dendrobatidae, Bufonidae, Craugastoridae, Strabomantidae, and Lepidodactylidae, which are associated with the leaf-litter, and Centrolenidae and Hylidae, more associated with trees. Additionally, we observed species from the Ranidae and Hemiphractidae families outside the plots. The preliminary results of the frog community analysis are quite encouraging; we found that both richness and diversity (measured by the Simpson Index) tend to increase along the chronosequence.

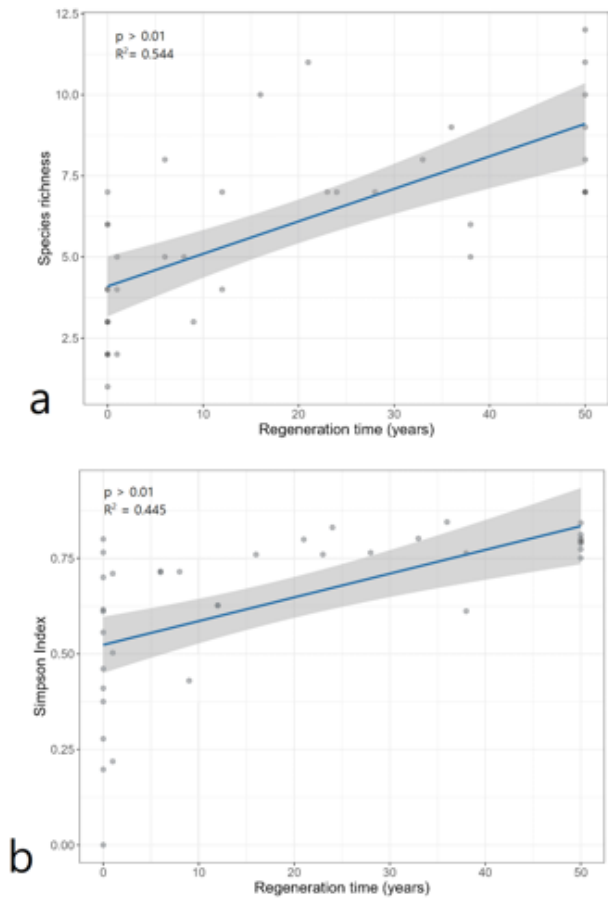


Figure 18: a) Frog species richness along the forest regeneration chronosequence, and b) Simpson Diversity Index of frogs along the forest regeneration chronosequence.

Shifting our focus to the arthropods that make up the frogs' diet, after completing the fieldwork, I spent several weeks presorting the stomach content of frogs. This involved identifying orders and different morphospecies within them and counting their abundance. It is incredible to discover the differences in feeding habits among various species. In the stomachs of some species, it was common to find a relatively large and soft item; in others, I counted around 200 tiny items such as oribatid mites, dwarf ants, and springtails. In total, I counted 6,363 prey items within the frogs' stomachs. Now, I am looking forward to uncovering more precise details that will emerge after the metabarcoding process.

Outlook

This year, I completed my fieldwork and left Canandé, an incredible place that taught me a lot, became my home for a long time, and gifted me with great friends and experiences. Now, I am excited to travel to Berlin next year and to analyze the results of the communities and functional diversity of leaf-litter frogs. Finally, I am very enthusiastic to learn about the results of the metabarcoding of frogs' stomach contents, to understand how to analyze this type of data, and to proceed with the network analysis.



Figure 19: Examples of photographs taken under the stereomicroscope of prey items from the stomachs of leaf-litter frogs: a) ant, b) beetle, c) mite, d) spider

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SP 3: Plant-pollinator interactions

Ugo Mendes Diniz, Technische Universität München

What everyone should know about my work

Within the REASSEMBLY research unit, Prof. Sara Leonhardt (Technische Universität München), Prof. Alexander Keller (Ludwig-Maximilians-Universität München), Dr. Gunnar Brehm (Jena Phyletisches Museum) and I compose the SP₃ team, which is responsible for disentangling the processes that underlie the recovery of plant and insect communities and their resulting pollination networks. Due to the enormous reliance of tropical plants on biotic pollen vectors (ca. 95% of species are animal-pollinated) [2], and simultaneously due to the astonishing rate at which we lose primary forests around the tropical zone [1], it is paramount to understand how resource loss affects pollinator communities, which species can withstand disturbance and what traits are responsible for it, as well as the driving factors of network recovery. The importance of closing these gaps becomes further inflated in ecosystems such as the Chocó lowland forests, where our unit is located, which is placed among the most threatened and rapidly vanishing biodiversity hotspots [3]. We must gain insight into the resilience and resistance of pollinators in the Chocó before they are no longer there. At this phase of REASSEMBLY, SP₃ has completed its second fieldwork campaign, finishing its core sampling period by collecting data from all 62 plots twice. We have thus gained knowledge from thousands of captured insects from diverse taxa and their pollen loads, as well as from hundreds of plant species found within the chronosequence. Here, you can take a peek at what we have been up to in the last year.



Figure 20: A selection of our focal groups of pollinators, displaying their incredible diversity. a - a nest of the stingless bee *Tetragonisca angustula* (Apidae: Meliponini); b - some colorful individuals of tiger moths (Lepidoptera: Erebiidae: Arctiinae); c - a few individuals of the orchid bees *Exaerete* and *Eufriesea* (Apidae: Euglossini); d - a large sphingid moth (Lepidoptera: Sphingidae).

What we do

In short, we employ several capture methods to sample as many pollinator groups as possible to get a comprehensive look at the community. An important aspect of our project is to understand how networks recover both during the day and at night, and for that we sample several groups of hymenopterans (stingless bees, sweat bees, orchid bees and cavity-nesting wasps) and moths (tiger moths and sphingids), respectively (Fig. 1). The usage of a combination of vane traps, fragrance traps, trap nests, active netting, and LED light traps in all plot types have proved successful in allowing for an extensive grasp of the pollinator fauna in the area. Along with SP₄, we will also delve into bat pollination via pollen samples collected from these animals. Not only temporally, we are also ambitious in a spatial sense.

The canopy is a rarely sampled section of the forest due to the logistical difficulties [4]. By using a pulley system, installed via bow-and-arrow, we can sample insects up to 35 meters above ground (Fig. 2) and gain insight from this mysterious stratum of the rainforest.



Figure 21: The setting procedure of canopy traps. a - First, we shoot an arrow tied to a fishing line over a branch in the canopy; b - Later on, we replace the fishing line with a rope that will serve as a pulley system for the traps (red circle).

A big part of our project is identifying and collecting trait data from insects and plants, which we will continue doing until roughly mid-2024, with the aid of specialists (Claus Rasmussen, Aarhus University) for bees, and Gunnar Brehm for moths). Additionally, pollen samples are being continuously metabarcoded by Alexander Keller's group, and in combination, interaction data and a well-resolved species list will soon yield our first results on networks and the role of functional traits in their recovery. Finally, we escape from our network-centered focus to explore a bit on how processes, specifically pollen flow and pollinator provisioning (i.e., the "health" of plant-pollinator interactions) fare and recover along the chronosequence. This is achieved by controlled pollination experiments on the field using caged phytometers and trap nests, respectively (more on this later).

Plans and reality

While our core sampling procedures have proven extremely successful throughout these two years, allowing us to capture up to ten thousand insects from different taxa and likely an equally high amount of interactions, as well as registering an incredible diversity of plants, a few aspects of our project did not go as planned, namely the processes mentioned above. First, our phytometer experiment, which would encompass rearing and replanting a target plant species on the plots to

measure its fruit set, was not carried out in the end. Despite several tries with different herb species, we were unable to grow hundreds of phytometer individuals in a nursery in the research area. It was immense work, especially for the parabiologists involved, but neither our initial target *Nicotiana rustica*, nor our second try *Chelonanthus alatus*, grew in sufficient numbers for the experiment. Due to the pressing timeframe, we unfortunately had to give up on this exciting side project. Secondly, our trap nests, set in all plots and also in the canopies, were initially aimed at capturing trap-nesting bees and collecting pollen loads for us to measure the quality of their provisioning and fitness (Fig. 3, a). Although very few bees colonized the reeds (Fig. 3, b), which hinders the entire subproject, we found a new, unexpected research opportunity: cavity-nesting wasps. We have so far captured hundreds of trap-nesting wasps (Fig. 3, c), which are surprisingly fond of our traps, and they also leave an interesting extra inside the nest – the remnants of insects that served as meals for the growing larvae. Now, we expect to delve into a whole new system, namely wasp-predator interaction networks and their recovery along the chronosequence, greatly widening the scope of SP3.



Figure 22: a - The trap nests used (initially) to capture cavity-nesting solitary bees. Although a few bees and pollen were collected (b), most of the samples currently being reared belong to wasps and their insect prey (c).

Results

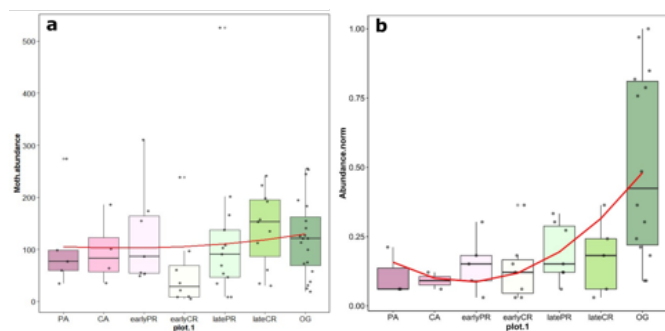


Figure 23: The distribution of pooled moths (a) and nocturnal *Megalopta* bees (b) along the chronosequence.

After completing the two years of sampling, setting 845 traps, and carrying out 248 hours of netting, we have reached the landmark of 10000 captured moths, 9200 bees, and 1240 plant occurrences from ca. 450 morphospecies. Apart from that, we also already have about 300 reed samples, which contained wasp individuals and often their prey. Quite a large dataset and exciting things are coming next! Although we still don't have enough interaction data at our disposal to show to you, we can present interesting abundance and richness patterns along the chronosequence. What strikes us as the most interesting so far

are the different responses of the insect taxa to the regeneration gradient. Nocturnal animals, for example, show contrasting trends as moths not showing a strong distribution pattern (Fig. 4, a) while nocturnal halictids (*Halictidae: Megalopta*) are mostly reliant on forests (Fig. 4, b). Understanding what causes these and other contrasting patterns is among the main current missions of SP3.

Outlook

We look behind at these two years with great joy for the amazing opportunity that it was working in the Chocó, and for the numerous fruits that it has yielded. We haven't said goodbye yet, as we will go on to perform our last campaign in March to wrap things up and to try to collect some pollen flow data. In the next months, we expect to get some key results, especially network and trait data, and with them to finally start untangling plant-pollinator (and prey-predator!) interactions within the unit. Stay tuned for the next newsletter!

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SP4: Seed Dispersal by Birds and Non-flying Mammals

Anna Rebello Landim, Senckenberg Gesellschaft für Naturforschung

What Everyone Should Know About My Work

SP4 continues its study on the reassembly and restoration of seed dispersal by birds and mammals during unassisted forest recovery. Our subproject is composed of two Ph.D. students, three PIs, two collaborators, and two parabiologists. While Marco Tschapka, Santiago Burneo, Santiago Erazo and Jefferson Tacuri focus on seed dispersal by bats, Matthias Schleuning, Eike Lena Neuschulz, Boris Tinoco, Jordy Nina-banda and I study dispersal by birds and other frugivorous mammals.



Figure 24: The SP4 team after a one week stay in Casa del Medio. From left to right: Jerson (substituting for Jefferson), Santiago, Jordy and Anna.

Seed dispersal is fundamental for restoration, as it allows plants in natural habitats to recolonize degraded ones [2]. However, studying the reassembly of seed dispersal can be a great challenge, as plants and frugivores are codependent. Frugivores depend on the presence of the fruits that they consume for survival, while plants depend on frugivores to colonize degraded sites [3]. Furthermore, the presence of both frugivores and fruiting trees depends on other environmental drivers, such as precipitation and temperature [1]. Thus, seed dispersal reassembly is shaped by an interplay of plant and animal communities' and species' responses to biotic and abiotic factors.

Additionally, seed dispersal involves numerous demographic transitions, from dispersal to seedling establishment and adult tree growth, influenced by various factors, both directly and indirectly related to frugivores [6]. While some factors are only indirectly related to frugivores, others have a direct relation, such as dispersal distance and the effect of gut passage on seedling establishment [5]. Different frugivores provide different services as dispersers, in the sense that they consume and disperse different fruits, but also that they provide different qualities of dispersal [4]. In a restoration scenario, for instance, a larger bird would consume larger fruits and disperse seeds over longer distances.

With this in mind, I want to understand the following.

1. The reassembly of communities of frugivores, fruiting plants and their interactions during forest recovery.

2. How seed dispersal functions re-establish along forest recovery.

Plans & Reality

This year, we successfully completed the data collection in the 62 plots. We were also able to collect seed rain data in all P-REX plots (this was done by the entire SP4 team).

Our field work involved observing frugivorous birds and mammals in different forest strata, capturing the interactions between these species and fruiting plants. For canopy interactions, we did focal observations using binoculars, and to record ground-level interactions, we used camera traps. Our fieldwork revealed a rich diversity of seed dispersal interactions. This year, observations were further enriched by surprising new species, such as the yellow-rumped cacique (*Cacicus cela*), black crowned Tityra (*Tityra inquisitor*), and the golden-winged manakin (*Masius chrysopterus*), the latter being a particularly special sighting, as it is rarely seen in the region.



Figure 25: Frugivory by birds recorded with camera traps. Top: orange-billed sparrow (*Arremon aurantiirostris*) pecking on a fruit at a regeneration cacao. Middle: pair of tawny-faced wood quails (*Rhyncortyx cinctus*) pecking on a fruit of *Brosimum utile* at an old growth forest. Bottom: Great tinamou (*Tinamous major*) trying to eat a seed of *Wettinia quinaria* at an old growth forest.



Figure 26: Frugivory by mammals recorded with camera traps. Top: an agouti (*Dasyprocta punctata*) burrowing a seed of cacao (*Theobroma cacao*) at a regeneration plot. Bottom: a tayra (*Eira barbara*) eating cacao at an active plot.



Figure 27: Unexpected camera trap captures. In the left, a juvenile brown wood-rail (*Aramides wolfi*) eating a frog and in the right, a bat eating fruits. Both captures were in pasture regeneration plots.

Results

In total, we have observed 4103 canopy and 682 ground interactions. We have built seed dispersal networks for each plot treatment: active, regeneration and old growth. At first glance, we are already able to see that interaction diversity and specialization have opposite patterns in the plot treatments (Figure 5). The Shannon diversity of interactions increases from the active ($H' = 3.04$) to the regeneration level ($H' = 5.19$) and then drops towards the old-growth ($H' = 4.51$). In contrast, the network specialization decreased towards the regeneration level. It was higher in active ($H'_2 = 0.7$) and old growth levels ($H'_2 = 0.48$) and lowest in the regeneration ($H'_2 = 0.46$).

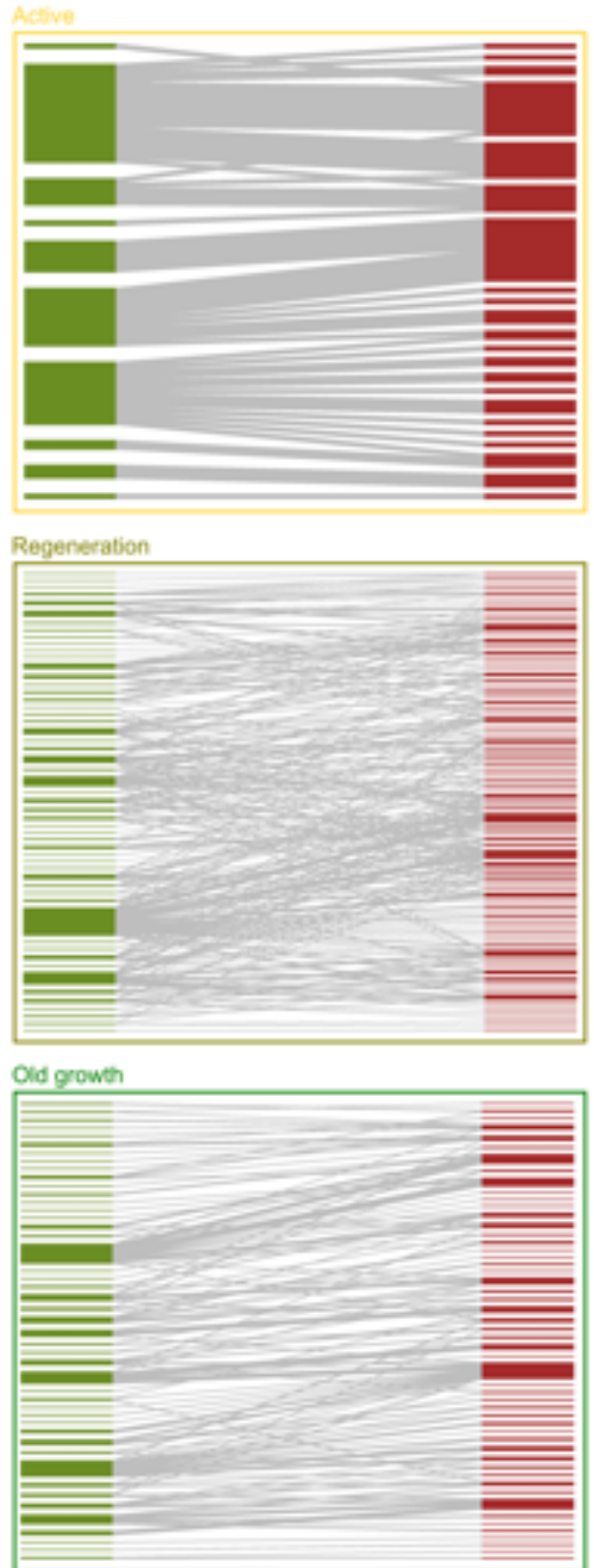


Figure 28: Seed dispersal networks from active, regeneration and old-growth plots.



Outlook

As we leave the Ecuadorian Chocó and the Canandé Reserve, we think about what we have achieved and learned. Our last season in the field gave us a lot of valuable information. Now, in terms of data collection, we still need to identify herbs, shrubs and smaller trees that were not sampled by CM and barcode the seeds from the seed rain. Moving on from data collection, we look forward to analyse our data and disentangle the dynamics behind the recovery of seed dispersal in the Chocó!



Figure 29: Sunrise in the last day of fieldwork.

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SP4: Bats and seed dispersal

Santiago Erazo, University of Ulm (Germany) - Pontificia Universidad Católica (Ecuador)

What everyone should know about my work

The SP4 team, we are a diverse group focused on seed-dispersal by frugivorous birds and mammals, and seed rain. Matthias Schleuning (PI), Eike Lena Neuschulz (PI), Boris Tinoco (main collaborator), and Anna Rebello Landim (PhD student) focused on seed-dispersal by frugivorous birds and non-flying mammals. Marco Tschapka (PI), Santiago Burneo (main collaborator) and I (PhD student) focused on seed-dispersal by bats. In addition, at different stages of the project we had the valuable collaboration of trained Parabiologists from the surrounding communities, mainly Jefferson Tacuri and Jordy Ninabanda, who became an indispensable part of our group during these two years of work.

This study is being carried out in the Ecuadorian Chocó, in order to contribute to the knowledge of this important region and to promote its conservation. The Chocó biogeographic region, located within the Tumbes-Chocó-Magdalena hotspot, is very important for its diversity and endemism [7] and faces constant and increasing threats generated mainly by deforestation for agriculture and timber activities [2]. In the face of these threats, it is necessary to understand how the natural regeneration of its forests takes place.

Seed dispersal is one of the bases for the initial processes of natural regeneration [4]. In Neotropical rainforests, the seed dispersal by frugivorous vertebrates is a crucial ecological process [3]. In addition, the ecosystem service of seed dispersal is a mosaic of subservices performed by distinct groups of frugivorous [6]. Frugivorous birds and bats are considered the main dispersal agents, and predominant the initial stages of forest succession [5, 1]. Differences between bat-fruit and bird-fruit networks in structural properties have been recorded, and support the hypothesis that those two disperser groups form different mutualistic modules [6]. In this context, our objective is to study the reassembly of plant and animal (frugivorous birds and mammals), their seed-dispersal interactions, importance and role in a forest recovery gradient, in the Ecuadorian Chocó.

Plans & Reality



Figure 30: Methodology: Camping evolution

Culminating our second year of fieldwork, we can say that so far we have satisfactorily fulfilled our planning, finishing with the sampling of the 62 plots previously established. We believe that as a team we were able to handle in the best way the different unforeseen events that could arise during the fieldwork. We observed an evolution in our work, and in how we managed our stays in camps and in the different satellite houses for extended periods. However, there are unforeseen events that we cannot control in the field, such as weather conditions that on some nights were not the most appropriate (e.g. heavy rains) and made our work difficult or limited, but we will always be exposed to this type of natural conditions.

Our fieldwork consisted of capturing bats to identify their diversity, for which we used six mist nets (6 m x 2 m), active between 18h30 and 24h00, for three consecutive nights in each plot, with a total of 6138 hours/net/plot of sampling effort. To analyze bat-fruit interactions, we collected fecal material directly from bats (defecating at the mist net) or by keeping them for a few minutes in a clean cloth bag. In addition, we collect pollen samples from the nectarivorous bats. Functional traits were measured on bats captured in the plots and, if necessary, the data will be supplemented with measurements in museum collections.



Figure 31: Methodology: mist nets

Preliminary Results

We observed among the 62 plots sampled, more than 2500 bats and more than 50 species were recorded. In addition, as interactions, it was possible to collect about 1000 faecal samples and about 50 pollen samples of nectarivorous bats. A superficial analysis of our preliminary data shows that there is a small group of species that predominate in the area, among them, *Carollia perspicillata* (fig.32), *C. castanea*, *C. brevicaudum*, *Dermanura rosenbergi*, *D. ravus*, *Rhinophylla aethina* and *Vampyressa thylene*. The seven species are present in more than 0.5 of the sampled plots and together account for almost 0.75 of the abundance of bats captured. On the other hand, about 0.6 of the species are uncommon to rare, and represent approximately 0.05 of the abundance recorded in the area.

We also observed that approximately 0.5 of the species recorded feed mainly on fruits and these represent more than 0.9 of the total abundance of bats recorded, being the dominant group in the area. The other 0.5 is distributed among species that may be nectarivorous, insectivorous, carnivorous or omnivorous, but only represent about 0.1 of the abundance of bats. These preliminary results demonstrate the important diversity of bats, their assemblage types and interactions in the Chocó region.



Figure 32: Interaction: *Carollia perspicillata* eating a *Piper* sp.



Figure 33: Bat diversity: *Vampyrum spectrum*



Figure 34: Chocó diversity: *Tamandua mexicana*

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SP5: Tree seedling recruitment and herbivore interactions during forest recovery

Eva Tamargo López, Philipps-Universität Marburg

Work progress

We have successfully completed our second year of sampling with the aim of shedding light on the resilience of tree seedlings and herbivores. Over the last 24 months, we conducted six replicates of the monitoring on the 39 selected Reassembly plots. In each round, we measured morphological parameters and herbivory of about 1000 seedlings. We have identified 156 morphospecies of tree seedlings, of which 70 % were collected and prepared for barcoding in spring 2024. We are currently preparing the next field campaign, which will start in March 2024 with the support of three great students: Stella Drechsler who will be studying the resilience of the seedling community after perturbation (PREX), Marco Hügel who will focus on the recovery of seedling-herbivore interaction networks along the chronosequence and Nikolaos Ioannidis who will be looking at how abiotic and biotic factors are linked to arthropod communities during forest recovery, as well as our amazing field assistant Lady.

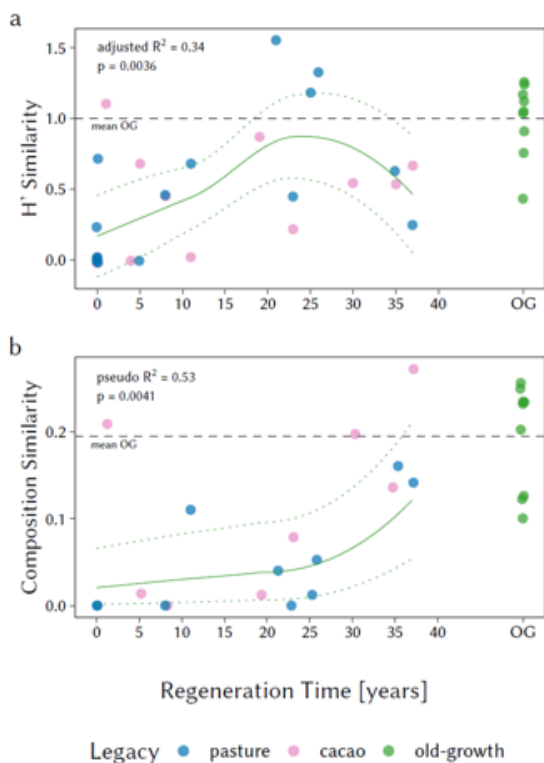


Figure 35: Secondary forest community properties recovery with successional age, measured as the similarity to old-growth forests. (a) Relative Shannon diversity (H'), (b) species composition similarity. Trajectories of secondary forest recovery are predicted from linear models with 95 % confidential intervals (blue regression line). Land-use legacies cacao (green) and pasture (red) are shown. Old-growth community property means is marked with a black horizontal dashed line. Old-growth plots were added as a visual reference.

Second field season-adult tree mapping

This year sampling season has been challenging, but beautiful. Thanks to Claudia Eberspach and Franziska Scheele, we introduced

a new sampling protocol, in which we mapped every tree in the surrounding of every PREX treatment. Although this comprised a lot of extra work, this as well gave us the information of the amount of adult trees surrounding every treatment, their species identity and size, as well as knowing if any of their branches is directly above of our seedling subplots. This information will be so valuable for us, and can help us to a better understanding of the seed dispersal.

Besides this, we carried the same former field work, identifying and measuring every seedling in our plots. There were some constraints in our work, some diseases, tons of mosquito and mud, but, as always, the beauty of the forests and its people kept us motivated all the way, helping us finishing our work with a smile.

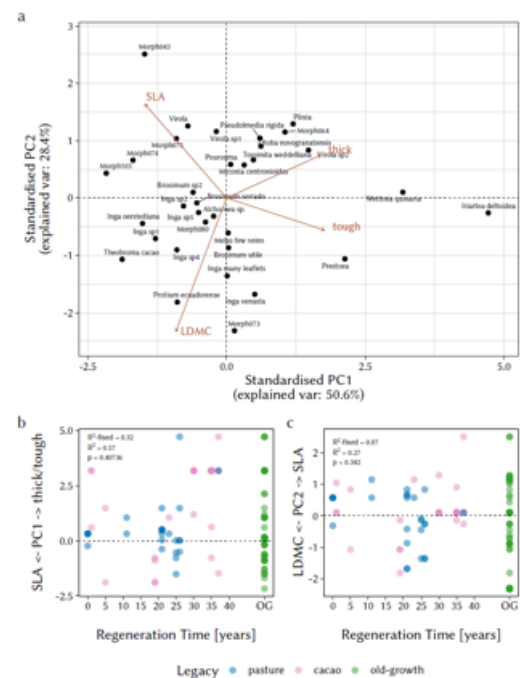


Figure 36: Principal component analysis (PCA) of multivariate trait associations across 33 tropical tree seedlings. (a) The first two axes represented 79% of variation in the data. Leaf traits: specific leaf area (SLA), leaf dry matter content (LDMC), leaf thickness (thick) and leaf toughness (tough). Each point represents one seedling (morpho-)species. (b) PC1 and (c) PC2 axes showed no significant changes in trait composition with succession and species found in old-growth (OG) covered the entire trait spectrum. Each point represents one individual seedling. Positive numbers stand for increase in (b) thickness/toughness and (c) SLA. Negative numbers stand for increase in (b) SLA and (c) LDMC.

Master theses

Using data of the first field campaign two master students finished their theses with 2023, analysing both the recovery of the seedling community and the herbivory network.

Elis Martinelli focused on the dynamics of tree seedling diversity, composition and their traits along the chronosequence.

We hypothesized that the seedling species richness would increase with forest age, and that the seedling community would resemble more the one in old growth forest as the forests grow old.

Our results showed an differentiated recovery speed for functional and species diversity. While species diversity and similarity to old-growth forest increased with successional age (Figure 35), species composition didn't show a clear pattern along the chronosequence or past land use,



but we found substantial within-group variability and with it high species heterogeneity.

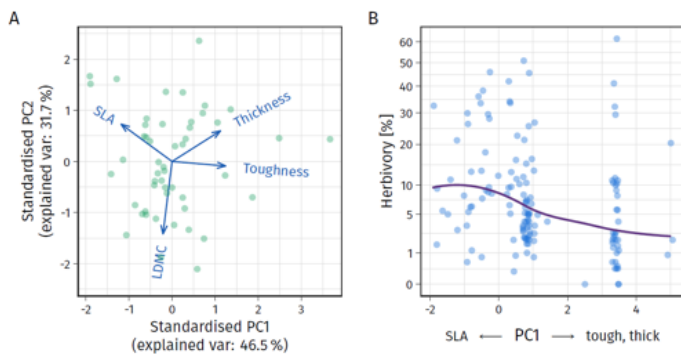


Figure 37: A: Biplot of Principal Component Analysis of seedling functional traits: specific leaf area (SLA), leaf dry matter content (LDMC), leaf thickness and leaf toughness. Each point represents one seedling morphospecies. B: Scatterplot of herbivory as leaf area loss in percent against the first principal component, which is loaded positively with leaf toughness and thickness and negatively with specific leaf area. Each point represents one seedling

Functional diversity and composition showed a stable high similarity to old-growth forests from early regeneration stages, without significant changes from acquisition to conservative trait composition along the successional gradient (Figure 36).

Regardless of legacy, the secondary forest tree seedling community resembled old-growth forest within 35 years from abandonment. Our results demonstrate the great recovery potential of naturally regrowing tropical rainforests. We will in the next year analyse the PREX data to shed light on the mechanisms promoting secondary forest recovery, which can contribute to optimise natural regrowth on abandoned land.

Lukas Werner studied the seedling-herbivore interactions along the chronosequences.

The interaction of tree seedlings with herbivorous insects plays a major role in the regeneration of tropical rainforests. We evaluated herbivory (measured as accumulated leaf area loss), compositions of damage types and their relationship with plant defence traits on the tree seedling community level along the successional chronosequence. The selected plant physical defence traits were thickness, toughness, specific leaf area and dry matter content.

We hypothesized that the tree seedling-herbivore interactions would accompany this trend and the network would become more complex (more damage types richness in oldest forests but less amount of leaf area lost).

Our results showed no influence of forest age in leaf area lost, but leaf conservative traits decreased the amount of herbivory Figure 37. Surprisingly, the richness of herbivory damage types decreased with successional age, but we detected no turnover in damage type composition.

Understorey perturbation had a negative effect on herbivory, on the contrary as animal enclosure, that had no effect on herbivory patterns Figure 38. These results help in the understanding of the complex interactions between herbivores and seedling community assembly of recovering tropical forests.

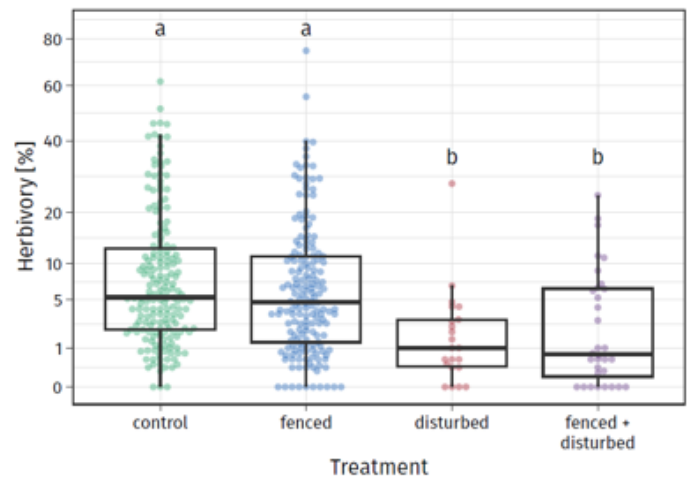


Figure 38: A: Biplot of Principal Component Analysis of seedling functional traits: specific leaf area (SLA), leaf dry matter content (LDMC), leaf thickness and leaf toughness. Each point represents one seedling morphospecies. B: Scatterplot of herbivory as leaf area loss in percent against the first principal component, which is loaded positively with leaf toughness and thickness and negatively with specific leaf area. Each point represents one seedling

Conclusion and outlook

Our work revealed a fast recovery of tree seedling communities and herbivory levels across the chronosequence. There is a high seedling community heterogeneity, that increases its similarity to old-growth forests. Additionally, we found consistently high levels of herbivory across all forest age classes with a high diversity of damage types that dropped throughout succession.

In conclusion, we showed that forest restoration based on natural regeneration can effectively contribute to the recovery of ecosystems and enhance biodiversity.

In a nutshell, our project is advancing very well as shown by the preliminary data presented here, ongoing analyses and new projects that will start in March 2024.

SP 6: Dung beetles and ecological Processes and the chronosequence

Karen Marie Pedersen, TU Darmstadt

What everyone should know about our work

Our sub-project studies dung beetles. As the name suggests, they often consume dung, which is not their only food. Dung beetles consume several other decaying matter types, including fermented fruits and carrion [2]. It takes a particular person to prepare the unappetizing baits that dung beetles prefer and dung beetle scientists require. So, who are the people who decided that dung beetles, with their strange habits, are worth studying? This year, our team consists of three supervisors, Nico Blüthgen, Thomas Schmitt, and Diego Marin, a Ph.D. student, Karen Marie Pedersen, a master's student, Jan Johan, and our field assistant Franklin Quintero fig 39. Collectively, we study dung beetles in the context of REASSEMBLY.

Dung beetles are some of the most amusing insects in the forest. They are relatively large and easy to spot. They will land next to you as you eat lunch, seemingly waiting for you to produce their lunch, and they often run into the large leaves of the undergrowth as they zoom through the forest with their characteristic buzzing of wings. From an ecological perspective, dung beetles play a role in two crucial processes within ecosystems: 1) they remove and feed on the dung of other animals, aiding in its decomposition, and 2) they secondarily disperse seeds, possibly increasing seed survival[4].



Figure 39: Franklin cleaning the fruit flesh off seeds for the seed removal and germination experiment accompanied by Leo.

Where I work - Field Impressions

I found this year to be particularly challenging, first, because of the gap in coordination. This meant that overnight, I went from planning an already ambitious field season with four product data sets, all with new, untested methods, to an entire second job's worth of fieldwork with an additional ten data sets. The number of people I was responsible for also increased from a team of three to two teams of five and four people, respectively. The two teams worked simultaneously, carrying out fieldwork, leaving me feeling like I always needed to be in two places simultaneously. This type of work has no real upside because it goes unnoticed unless it fails. However, we have a great team, and I am very


grateful for the support of the entire field team at Cananadé, particularly Bryan. Whenever Bryan is part of a team, things work better. He is good at thinking about the best way to accomplish a task and often finds good solutions to unexpected problems. The support of fellow PhDs, in particular, Arianna, who made an outsized contribution to the collection of leaf litter and leaf decomposition data this year. I can confidently say that these data would not have been collected without her. For SP6, we have an excellent master's student, Jan, whose software skills and general spirit of teamwork made a big difference in the data collection this year. Without their contributions, neither SP6 nor the larger project would have collected much data this year. I was very grateful when Edith joined our team and smoothly took over in May and I could focus again on one project.



Figure 40: This is the view from the lab, which is a wonderful daily reminder of how lucky we are to work in such a beautiful place.

Data collection what worked and what did not work

This was the year that SP 6 became adventurous in our data collection. The methods from the previous years for studying dung beetle species communities are well-established and relatively easy to execute. However, this year, we focused our data collection on the processes of dung removal, seed removal, and burial across the chronosequence and within the context of the PREX. As hard as communities are to study, processes have fewer well-established methods, which makes them harder to study. We approached this challenge with two major experiments this year. The first involved our dung beetle cameras. Most studies of dung removal place a standardized quantity of dung in the field and then return one or two days later and to quantify much dung is removed. In an area with a healthy dung beetle population, this is typically all the



dung; in an area with a less healthy population, this is some of the dung, though the remaining dung is unlikely to be removed because it will have lost its attractiveness qualities, e.g., it is less smelly and wet. This means that the resolution of the data is insufficient to see differences in dung removal rate, which in our study system is expected to be at the level of hours, not days. We needed a different method to understand this across the chronosequence: enter the camera! The camera also allows us to collect additional types of exciting data. One of those types of data is dung beetle activity windows. Under normal conditions, these would be labor intensive to study because a person would either have to sit and watch a bait or empty a pitfall trap every hour or so. Activity windows could be significant in understanding the dung beetle diet. One of my hypotheses is a diurnal, nocturnal split in access to dung resources, which we saw in preliminary gut content analysis (paper accepted and coming soon). Cameras should also allow us to characterize the dung removal and, at some level, which beetles contribute to the dung removal process. Initially, I was hopeful that we could also characterize dung beetle species. However, the preliminary data suggests that it will not be possible for us for all species because the lower-quality images that are not always in focus. Jan also had the idea to mix colored beads of various sizes into the pig dung and quantify the remaining beads and the size of the beads. This could help us to understand better which beetles disperse seeds of which size because they can be seen on the camera when not covered in dung. Our second experiment was initially meant to test if germination rates of seeds were reduced in the absence of dung beetles across the chronosequence. While I have yet to analyze the germination rate data, this experiment presented many difficulties.

Dung beetle cameras

The dung beetle cameras were one of the most fun and frustrating things I have ever worked on. We chose a modular design for the cameras, which meant we could customize all the parts. Modular cameras have several advantages over traditional camera traps for researchers. They tend to be a little cheaper because the researcher creates the camera. They can also repair broken components without needing to send the cameras for expensive international repair, the software can be optimized for the type of data collection and data processing pipeline of the researcher, and the setup can enforce the collection of needed metadata for analysis (a step that is often missed or incorrectly executed with traditional camera traps). One downside is that it is tempting to be in an infinite optimization loop and never produce a working prototype. Another is that it requires much more technical knowledge to operate successfully than a traditional camera trap. Finally, hardware has shortcomings, and once you make a choice, you must work within the bounds of that choice. I had read a few papers about modular cameras based on Raspberry Pi boards. This seemed promising because they are generally considered relatively easy to program, and there is a lot of sample code for similar projects published online. In addition, the boards are small computers with ports for monitors and keyboards, making programming accessible and straightforward. However, last year, when I was looking for the supplies to build our cameras, I found a shortage of Raspberry Pis due to global supply chain issues. All available Raspberry Pi boards had increased in price from tens of dollars to over one hundred. This was an unjustifiable expense. Not having anticipated this, I panicked and began to look for alternatives. I found the ESP32CAMs, which are a bit less user-friendly and have slightly fewer easy-to-implement plug-and-play parts but are incredibly cheap. Only €9 per camera with the ESP32 cam MB adaptor (the adaptor lets you connect it to the computer to program it). The ESP32 meant fewer easy options for the camera lenses. The ESP32 not only required that we write software in C/C++ Arduino

language, which I have never learned, but also meant I had no personal contact with experience to rescue me. At this point, I was unsure that the idea would work in the required time frame and began questioning our entire approach. However, the alternative traditional camera traps I considered with an adjustable lens for a shorter focal distance were no longer being manufactured.

If I wanted this to happen, we had to figure out how to make it work with available materials. I bought some ESP32 cameras and got a manual [5] that covered all the relevant aspects of writing software and selecting hardware. With the manual in one hand and ESP32 in the other, I started trying to follow the written instructions when I encountered the first obstacle. I could not get my computer to recognize the existence of the ESP32 when it was connected to my computer, which meant I could not program it. I tried every possible troubleshooting tip on the Internet, and nothing worked. Finally, someone told me I should try on a Windows computer, and I asked if we had any that I could use; fortunately, we had a very paired-down Windows mini-computer, and much to my delight, that worked instantly, no troubleshooting required! Now feeling like I had the entire world at my disposal, I tried to upload the simple script I had written to test if the camera could take and store enough photos and if our power bank would provide enough power to the camera to keep it running for 48 hours. This is when I ran into obstacle number two, I could not get the script to upload to the camera consistently. I took the camera small computer, key board and mouse home to the US with me for Christmas to help trouble shoot. The holidays proved a bit busier than I expected and I did not make much progress. I started to wonder if maybe I had been too fast dismissing the Raspberry Pi maybe we could borrow enough? The one's I thought I might be able to borrow would require us to carry motorcycle batteries into the forest along with the camera stands, and this is impractical given the rugged terrain in Canané. It was around this time in I also learned we would not have a coordinator for the project and offered to fill the gap in coordinating the fieldwork. This meant I had no time during the day to work on my cameras and split my day first by doing the planning for the Central Modules fieldwork and in the evenings tinkering with the cameras. It was a bit of an obsession and would wake up sometimes in the middle of the night and to tell my boyfriend my new idea to solve this or that problem, he was understandably a bit annoyed. It was obvious that I would never succeed in the given time frame. Normally I would have postponed the fieldwork until we had a functioning prototype. But that was not really an option in this case as I was also responsible for the Central Module fieldwork which needed to happen for other sub-projects. This was when I asked Jan to help and we started to talk about our advancements, he took over the writing of the software, and I continued to test the hardware and find enough supplies for the ten cameras we would need in the field. I based most of my decisions on a published modular camera design [1]. Nico suggested that we ask the University Werkstatt for help in securing the cameras to the insides of the Tupperware we used for camera housing, and they finished creating the hardware in a much more professional way than I would have thought possible. They probably could have made the whole thing more professionally if we had more time to involve them. Somehow, I arrived in the field with a prototype, that was still not yet ready to collect data, but fortunately Jan came a few weeks ahead of the scheduled start of SP 6 data collection took over the hardware and the software from there. This allowed me to train the first round of CM field workers. Before starting work with the second round of sampling where we planned to start the data collection for SP 6. It is a bit of a miracle that the cameras worked at all and I think Jan really deserves credit for this. The data from these cameras has not yet been processed however, looking at the images I am confident that we will produce

some novel insights into dung removal, dung beetle activity windows, and which functional groups of dung beetles are responsible for dung removal. We also included colorful wooden beads which can be tracked, this could provide interesting insights into secondary seed dispersal by dung beetles.

Seed removal rates and germination rates

In the attempt to test the hypothesis that dung beetles will remove more and larger seeds as the forest ages and that these seeds will have an increased rate of germination when secondarily dispersed by dung beetles. We created standardized seed mixtures with seeds ranging from a length of 1 mm to 30 mm, representing the range of seed sizes we have previously observed in dung balls. These seeds were mixed with 200 g of pig dung. We paid Don Freddy (the man with the most pigs) to collect pig dung for us in standardized quantities. This meant he waited for the pigs to poop and collected it before the pigs could step on it and mix it with the dirt. We opportunistically collected seeds from local trees when there were enough seeds available. Most tropical seeds are recalcitrant, which means that they are meant to sprout almost immediately and will die under normal seed storage conditions. This is in contrast to most commercially available seeds that fall into the category of orthodox, they can be frozen or dried and will survive. There is really not much useful information about storing recalcitrant seeds, the overwelling consensus is that they should be planted as quickly as possible. The year before I had attended a workshop community-based reforestation and seed banking. The materials from this workshop suggested that even recalcitrant seeds could be stored short term either by removing the fruit flesh and drying them a little so they did not mold, but not so much that they die or they could be placed in the refrigerator for a short period of time. I had personally seen mold come in after one day so I knew that we would not be able to set up any experiments in Tesoro, or Casa del Medio if we wanted to use refrigeration as a storage method. For this reason I choose to dry the seeds, and set up a preliminary and finally seed germination test with ten seeds of each of the included species. It took us 11 days to collect enough seeds for half of the plots, given that it would also take us one month to get to all the plots I decided we would set up the first round with the seeds we had, and then collect again for the second round with the seeds we could find then. This also gave the seeds a better chance of actually germinating during the experimental trials because this would reduce the time needed to store them. We set up our experiment within the PREX framework, including one dung pile exposed to dung beetles and one with a dung beetle enclosure. We also decided to take some additional data, including number of seeds present when we returned to take down the dung beetle enclosures, number of tunnels as a proxy for number of tunnellers, and length (of the longest diameter) of the tunnels as a proxy for the number of dung beetle species creating the tunnels. Dung beetles of different sizes will create different sized tunnels. We also created a crudely estimated canopy cover directly above the 2 m x 2 m plot. Once we set up the first plots and went back to check the seed removal, it became obvious that the planned 48 hour cycle was too short and dung that had the dung beetle enclosure over top of it was still attractive, which would mean that the germination data would not tell us anything about the exclusion of dung beetles. So we had to extend the revisit time to four days. This extended the field work for SP 6 beyond what was originally anticipated and meant that I had to cut down on the number of planned revisits to plots.

Preliminary Results

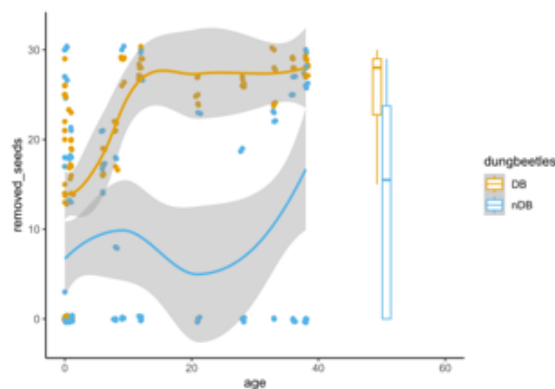


Figure 41: Scatter plot showing the removal rate of seeds (y-axis) across the chronosequence (x-axis), with dung beetles (DB) and without dung beetles (nDB). When dung beetles are excluded fewer seeds are removed, as the forest ages seed removal increases.

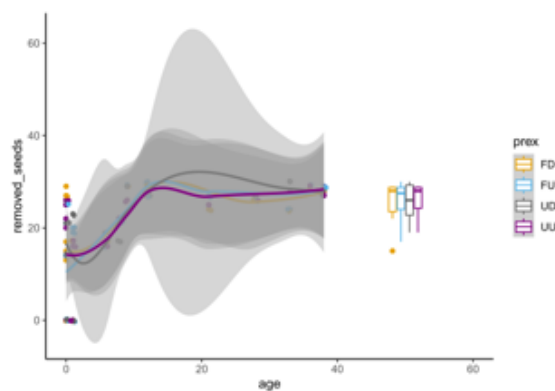


Figure 42: Scatter plot of the seed removal (y-axis) across the chronosequence (x-axis) in all PREX treatments (FD = fenced disturbance, UD = unfenced disturbance, FU = fenced undisturbed, UU = unfenced and undisturbed). This plot only includes data from the treatment that allowed dung beetles access to the dung. As dung beetles fly it does not seem likely that there should be any difference between PREX treatments.

This year we have not have many new results we can present but we are working on turning our data into results. I returned to Germany in August I began to finish some loose ends from last year, then entered and cleaned the part of the field data I did have. Data from Casa del Medio and a few other plots is still missing as those data just came back in a notebook with Edith in the beginning of this month (December). Dung removal rate is something we will work on quantifying next year. The photos themselves are not really impressive as standalone images. However, when looking through the images for just one plot I was fascinated by how much information is in these images. I could see a dramatic change in the dung community from early evening when the community is dominated by stingless bees. Then there is a shift as the dung beetles arrive. *Deltochilum* sp. individuals are possible to identify as they are large. There are several individuals of these large nocturnal rollers until close to 22:00. Then all the dung beetles leave for a few minutes and two individuals of a large *Deltochilum* sp. arrive and are on the dung until after midnight, they are not really making balls but hanging out on the dung and the two spend a lot of time right next to each other fig

43. If this is a common pattern it could indicate that the beetles first arrive and form balls for their offspring and then later feed. These types of data could help us better understand the activity windows for different dung beetles.



Figure 43: Images of the dung community from 18:29 until 1:17 the next day. A) An image of the dung with stingless bees which were present from 18:29 until 18:56. B) Image of the peak abundance of large *Deltochilum* sp. beetles. They make a lot of balls and roll them away. C) Image of two *Deltochilum* sp. that arrive after the rest have left, these two stay for over three hours.

Jan also mixed brightly colored beads of different sizes with the pig dung it is also possible to track some of the beads as the dung beetles incorporate them into their dung balls. Different-sized beads are different colors. This could allow us to better understand which dung beetle species are dispersing which seeds and the relative contribution of rollers versus tunneler. This seems like it could be a promising data set and an interesting method for future dung beetle studies.

We have some preliminary results from this year for the seed removal experiment as well. When dung beetles are excluded the removal rate of seeds in dung is much lower overall than when dung beetles are not excluded fig 41. This supports the hypothesis that dung beetles are important secondary seed dispersers. In addition, seed removal increases across the chronosequence. Dung beetles can fly and given that a distance of 40 m between pitfall traps is considered the standard for trap independence [3] it is unsurprising that there does not seem to be an effect of PREX treatment on seed removal across the chronosequence when dung beetles are not excluded fig 42. I am excited to analysis the small germination data set, to see if we were able to rescue any useable data for germination rates.

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SP7: Interactions between saproxylic insects and consequences for wood decomposition

Nina Grella, Universität Bayreuth

What Everyone Should Know About My Work

The research aim of SP7 is to study the interactions between insects and dead wood as well as the contribution of insects to wood decomposition processes. For our study of saproxylic insects, Ana and I work very closely together in the field. Together we set up large experiments and later focus on the influence of different insect groups. While Ana focuses on saproxylic beetles, I focus on ants and termites. This year we spend one field season in spring and one in autumn in the forest for conducting our experiments.



Figure 44: In WP₃ we exposed dead wood pieces from five different tree species on each plot. After hanging them into emergence chambers for five months under our students' house we collected the insects that emerged from the wood

Impressions from the field

This year's experiments focused on WOOD, WOOD and more WOOD! Last year in autumn 2022 we already practiced our wood handling skills when we have set up our experiment WP₃. We had placed one wood piece each from the five tree species Guaba, Sapanillo, Cacao, Mascarei and Fernán-Sánchez into each of the 62 plots. Then we gave the wood 6 months' time to get colonized by different insects and finally retrieved all woods in spring 2023 to the station in Canandé with great help from our parabiologist Holger and his mule muñeca. At the station we placed the wood into emergence chambers that we hung under the house that we lived in. After the chambers were hanging for five months under our house, we stopped collecting the emerging insects that fall into ethanol in autumn 2023. Next year I am planning identify the ant and termite species that were reared in the woods. The aim of this experiment is to understand which species colonize the five different wood species and which species do co-occur or exclude each other in the same wood pieces. Simultaneously when we retrieved the woods of our previous experiment we set up an insect exclusion experiment in the 32 PREX plots. For this experiment with the name WP₅ we have put 32 pieces of Guaba wood into each plot. In addition to the PREX treatments with soil disturbance and large mammal excluding fences, we added 4 additional treatments in each subplot for determining the contribution of different insect groups to dead wood decomposition.

In doing so, we have placed the wood into cages and metal trays that allow wood access either to all insects, to termites only, to beetles and ants only or to no insects at all. The dead wood decomposition rate was measured as mass loss of the wood pieces. Whereas getting the wood to the plot with our mule and installing them into the cages was the easy, taking the measurements and keeping an overview over 1024 pieces of wood was the hardest part of our field work so far. The logistics to transport wood to the station, cutting it and taking several measurements for estimating the volume, fresh weight and dry weight was very challenging, because we had to mark every individual wood and keep track of the measurements and the plot treatment and position where we placed each wood. In total we had 1024 pieces of wood and our main challenge was to keep an overview and not to confuse the individual pieces. But our team learned a lot about managing the deliveries, the storage and the handling of wood. In our second field season in autumn this year we retrieved half of the woods after they spend 6 months in the field and we managed to establish an efficient routine in wood measuring and handling learning from our experience in the previous field season. I am very thankful that our project got much logistic support for our challenging field work from the Canandé station managers and the Tesoro Escondido staff as well as from our parabiologist Holger. Next year in spring we will retrieve the second replicate of woods to measure the decomposition rate after 12 months.

My work in Bayreuth

Between field work I organized insect samples in Bayreuth, that I collected in my very first field season in 2022. Back then I sampled ants and termites in naturally occurring dead wood and in the surroundings. After spending long hours with my samples under the stereo microscope I was able to separate 2427 individual ants and 203 individual termites for identifying their species identities using DNA barcoding. Based on these results I want to analyze the communities of saproxylic ants and termites along the forest regeneration gradient.



Figure 45: In WP₅ we placed Guaba wood on the plots and excluded different insect groups from colonization for measuring their contribution on dead wood decomposition. After six months in the forest the woods were already colonized by fungi

Outlook into 2024

In the last two years I spend a lot of time with my team in the field to collect all kinds of data and in 2024 we will finally be rewarded with



much data to analyze. In spring I will be expecting my barcoding results of ant and termite communities inhabiting natural occurring dead wood to be ready for analysis. Simultaneously I will start identifying the insect species that were reared in the five wood species. Our last field season for the SP7 project will be conducted in spring next year where we will retrieve the second batch of woods from the PREX plots in order to get information of wood decomposition rates after a year in the plots. So I will be expecting a year full of data, analyses and time spend at the stereo microscope.



Figure 46: *Wasmannia auropunctata* that was collected in natural occurring dead wood

SP7 Deadwood and saproxylic insects

Ana Falconí López, Universität Würzburg



Figure 47: Holger, Ana and Nina walking to the plots

What everyone should know about my work

In SP7 we investigate deadwood decomposition and the interactions between saproxylic insects, fungi, and deadwood along the forest recovery gradient.

During the fieldwork, Nina and Ana collaborate closely and perform the majority of the sampling and experiments together. Ana focuses on saproxylic beetles and fungi, whereas Nina explores social insects like ants and termites.

This year, in our third work package (WP₃), we exposed wood logs from five different tree species on each plot (62 plots) and analysed the ant, termite, beetle, and fungi communities that colonised the deadwood. The resulting interaction network gives important insight in which insect and fungus species are most important in colonising and decomposing deadwood in the different recovery stages.

Finally, in our fifth work package (WP₅), we want to measure the contribution of termites, ants, beetles, and fungi to deadwood decomposition. We performed an insect exclusion experiment on the 32 PREX plots (PREX treatments with soil disturbance and large mammal excluding fences) and we will measure the contribution of the single taxa depending on forest age, disturbance, and the exclusion of large mammals.

With these experiments, we want to shed light on the relationships between species identities, functional traits, and contribution to deadwood decomposition of saproxylic insects and fungi in the different forest regeneration stages.

Impressions from the field



Figure 48: WP₃ experiment: we removed exposed five deadwood from different tree species on each plot after six months

This year our SP had two field campaigns (Figure 1). The first was conducted from February to April and the second from mid-August to October. During these campaigns, we worked with a lot of wood; 310 from the emergence chambers (WP₃) and 1024 from the exclusion experiment (WP₅).

Last year we had already placed one wood piece each from the tree species Sapanillo, Cacao, Guaba, Fernán Sanchez and Mascarei into each of the 62 plots. We left the 5 tree species for 6 months to allow the insects to colonise them. Then, in the spring of 2023, we carefully removed the wood (Figure 2) and took it to the Chocolab in Canandé. We first took the samples for fungi in the lab and then we hung them in the emergence chambers under the student house that we lived in (Figure 3). Our parabiologist Holger and his mule helped us with all the logistics.



Figure 49: WP₃ experiment: student house, emergence chambers and Holger

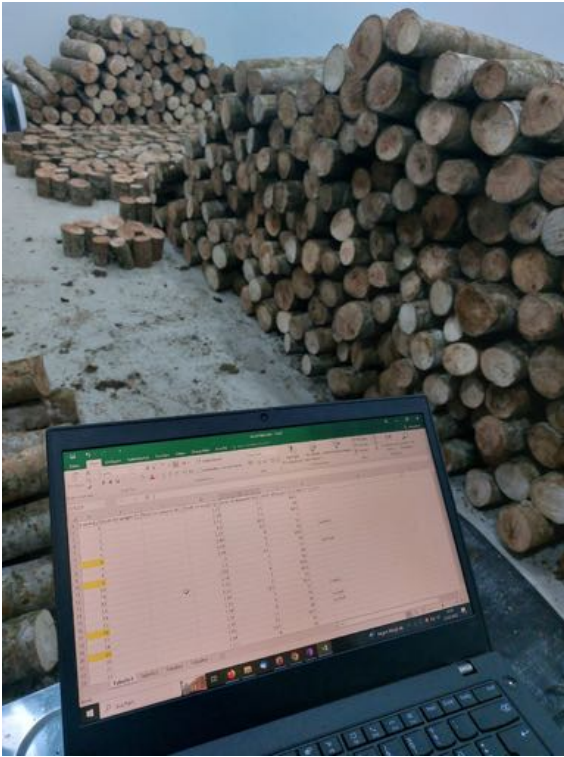


Figure 50: WP5 experiment: processing the wood before placing it on the plots (measurements and data)

For our exclusion experiment (WP5), before going to the field we had to do a lot of work preparing the wood, as we had to take several measurements (length, diameter, weight) and mark them before taking the 1024 woods of Guaba to the field; we made a table with all this data before placing the wood in the field (Figure 4).

While removing the five pieces of wood from each plot (WP3), we set up our exclusion experiment (WP5), which involved placing 32 pieces of wood (Guaba) in each PREX plot (32 plots). For the exclusion experiment we placed 3 different cages and metal trays that allow wood access either to all insects (wood without a cage), to termites only (wood in a cage with big holes in the bottom), to beetles and ants only (wood in a cage with big holes in the sides and top) or to no insects at all (wood in a cage without big holes) for each additional treatments in each subplot to determine the contribution of different insect groups to deadwood decomposition (Figure 5).



Figure 51: WP5 experiment: exclusion experiment, two pieces of wood in 3 different cages and without cage

In our second field season in autumn we retrieved half of the woods after they were 6 months in the field (Figure 6). This time we were more efficient taking the measurements than in the previous fieldwork.

Processing the woods before leaving them in the field and processing them when they were removed after six months was a challenge. This was the hardest part of the work because we had to organise the delivery of the wood, we had to cut the wood, we had to take the measurements, and we had to identify which marked wood goes to which plot, to which treatment and to which type of cage. But with the support of the station managers Katrin and Julio, our amazing parabiologist Holger and Yadira from Tesoro Escondido, we were able to get everything done on time and without problems.

Next year in spring we will retrieve the second replicate of woods to measure the decomposition rate after 12 months.



Figure 52: WP5 experiment: after 6 months in one of the cages (cage without big holes) we can see only fungi

Laboratory work

After the fieldwork, I was able to identify my beetles from the emergence chambers (WP3). I spent most of the time in Udla's lab organising my insect samples. I identified almost 50 morphospecies of beetles and I keep moving forward with my beetle catalogue and my databases (Figures 7-8).

Outlook

Next year we are planning to have the last field campaign in Canandé and Tesoro Escondido. We have to retrieve the second batch of woods from the PREX plots in order to get information of wood decomposition rates after a year in the 32 plots.

In addition to all the data collected in this two years of fieldwork, I will receive the barcoding results to continue with the analysis of the beetles and the fungi samples.

Also, in 2024, we will have two workshops, the first one is planned in Germany (January) and the second one is planned in Ecuador (March).



Next year I will have a lot of data to process, a lot of writing, a lot of lab work and two amazing workshops.



Figure 53: Working in Udla's lab with my beetles samples from the emergence chambers

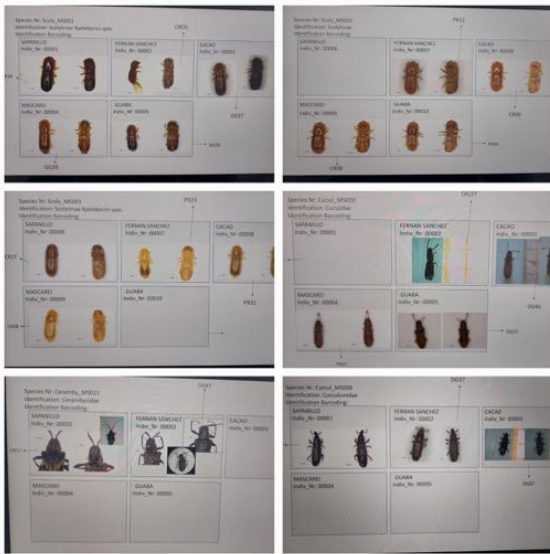


Figure 54: Beetles catalogue

SP X - Spider Monkeys and Seed Dispersal

Malika Gottstein, Uni Freiburg

Background

In tropical rainforests, large vertebrates are particularly important as seed dispersers, as tropical tree species often produce large seeds to facilitate seedling survival under very difficult light conditions [6]. Spider monkeys are the largest arboreal frugivores of the Chocó and are highly specialized on the consumption of ripe fruits, including large seeds which generally cannot be dispersed by other mammalian frugivores [2]. Spider monkeys occupy large home ranges and have higher daily travel length than other frugivores, giving them an outstanding role for ecologically important long-distance dispersal events [7]. The spider monkeys encountered at our study site in the Ecuadorian Chocó belong to the subspecies *Ateles fusciceps fusciceps* (brown-headed spider monkeys), of which only a few hundred individuals persist in the wild [1, 3, 4, 5].



Figure 55: Seeds of *Pouteria* sp. dispersed by spider monkeys.

Who we are

The project was planned by Malika Gottstein, Katrin Heer (Albert-Ludwigs-Universität Freiburg), Eckhard W. Heymann (Deutsches Primatenzentrum) and Citlalli Morelos-Juárez (Fundación Tesoro Escondido). The field work was carried out by Malika Gottstein, Patricio Encarnación and Ariel Villigua (parabiologists from Tesoro Escondido).



Figure 56: Field team at Reserva Tesoro Escondido.

Aims

We aim to assess the role of spider monkeys in seed dispersal at our study site. We want to know how far spider monkeys move, which and how many seeds they consume and disperse, and how they impact the genetic diversity of the tree species they disperse.

Plans & Reality

The initial plan was to work in the undisturbed forest in Tesoro Escondido, as well as in selectively logged areas. Although we did a one-week excursion to areas used by the wood company Verde Canandé and collected material for genetic analysis there, we will focus on Tesoro Escondido and unfortunately will not be able to draw a comparison to disturbed forests. The communication with the wood companies, as well as the access to the areas of their economic activity, proved to be too difficult and time consuming. In Tesoro Escondido, we would have liked to follow groups of spider monkeys during the whole day, but the deep slopes and difficult terrain made it very difficult.

Methods

In 2023, we spent six months in the field, from March to August. We spent most our time in Tesoro Escondido, where we walked transects (mostly trails A and Cordillera) to look for groups of spider monkeys. When we located a group, we followed them for as long as possible, taking data on group composition and movement, marking feeding trees and collecting fecal samples. We collected genetic samples of three tree species frequently consumed by the spider monkeys (*Brosimum utile*, *Pourouma guianensis*, *Hortia brasiliiana*) and set up camera traps on the ground to identify other dispersers of these trees. We conducted germination experiments to assess the impact of spider monkey gut passage.



Figure 57: Seeds from spider monkey feces.

First results

During 148 contact hours on 63 days, we recorded 330 feeding events on 82 plant species from 33 families. 73% of the feeding events involved ripe fruits from which spider monkeys swallowed the seeds. We collected 283 fecal samples containing seeds of 60 morpho species. We conducted germination experiments using 221 seeds from 9 plant species regularly consumed by spider monkeys. Seeds collected from feces showed a higher germination rate (64%) than seeds collected from ripe fruits (29%). We directly observed 29 dispersal events, in which we were able to clearly assign a mother tree to seeds found in spider monkey feces. Seeds were deposited at distances of 3 to 665m from the mother tree (mean=221 m, median=230 m).

Outlook

The next steps will be to finish and analyze the spider monkey baseline data set, including data on group composition and movement. To finish the ecological data set, we still need to identify around half of the seed morpho species found in spider monkey feces. We will start lab work in the beginning of next year. We will use the genetic samples collected in the field to determine genetic diversity measures for the sample sites as well as spatial genetic structure as an indirect measure for dispersal distances.

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