Mysteries unravelled: The unique plant-insect food web of tropical forests

Tropical forests are widely acknowledged as immeasurable treasures of biodiversity, at every single link of the food chain. The ERC-funded Diversity6continents project took special interest in their plants and insects, to find out how so many species can cohabit in unbelievably small areas.
‘Our house is on fire’. This metaphor, used to describe the dramatic fires affecting the Amazon at the end of last year, also sounded as a wake-up call for the scientific community. Now is the time to unravel the mysteries of tropical rainforests, not just for the sake of scientific knowledge, but also to highlight their value and, hopefully, lead to better conservation strategies.

In this race against time, every effort counts. Take the Diversity6continents project for instance. By studying plant-insect food webs in Papua New Guinea, Cameroon and Panama, the project has been deepening our understanding of what makes their tropical forests so diverse in comparison to our own temperate ones. But there is even more to it than it seems: the project’s unique approach, which directly involves local communities, could ultimately strengthen their own support for conservation strategies.

We found out more during a thorough discussion with Vojtech Novotny, principal investigator of Diversity6continents.

**The fact that tropical forests host most biodiversity could easily be considered as self-evident. What pushed you to further investigate the reasons behind this reality? What knowledge gaps did you aim to overcome?**

Vojtech Novotny: Tropical forests are well known for their high diversity, but we know surprisingly little about the precise, or even approximate, dimensions of this diversity. This is particularly true for insects. We have estimated that there may be as many as 9,600 different species of herbivorous insects coexisting locally in a lowland rainforest. These species each have one or more host plant species, and a whole suite of parasitoids, pathogens and predators.

Without mapping and understanding this complex web of interactions between species, we cannot hope to understand the behaviour of forest ecosystems. For instance, what happens when we remove, or add, a particular species? We do not have an answer to such a simple question. We cannot claim we understand a system without being able to predict its behaviour.

**What’s so special about plant-insect food webs specifically?**

The key mystery of tropical diversity is the sheer number of plant species able to coexist. In our research plot in Papua New Guinea, we found 560 woody plant species growing within a 1x0.5 km area. Such diversity contradicts the niche theory,
how do you explain such discrepancy?

Perhaps the most promising theory is the Janzen-Connell hypothesis, suggesting that vegetation is controlled by herbivores or pathogens in a density-dependent manner. This means that there is a penalty for being too abundant because abundant species are disproportionately targeted by their natural enemies. This is why there are so many pests in forest plantations. The theory was published 50 years ago, but it is only now that we are starting to test it rigorously, looking at herbivorous insects and fungal pathogens.

Our research, recently published in the Journal of Ecology, shows that herbivores keep rainforest vegetation diverse, even during ecological succession when the rainforest regenerates after disturbance. Plant competition was supposed to be all that mattered in early secondary succession, but it now appears that insects play a role in shaping successional vegetation as well.

Research goes in two directions. We first provide painstaking documentation of complex plant-herbivore interaction networks that can easily have 40,000 distinct plant species herbivore species interactions in one place, and then conduct rather crude experiments where we kill all insects from a patch of vegetation using insecticides and examine what happens next. The challenge is to combine these lines of research, especially due to the fact that such forms of experiments are now considered to be rather controversial, so that we know precisely which herbivores are more or less important in shaping rainforest vegetation.

what makes this approach particularly innovative?

Instead of using the standard botanical protocols which consist in monitoring trees with stems more than 5 cm in diameter within a 1 ha area, research in the tropics has generally upgraded them to a 50 ha area and all stems more than 1 cm in diameter. This 300x increase in the number of trees per plot was first implemented in 1980 in Panama.

Our research provides a similar upgrade for plant-insect food webs, from limited
samples from individual trees to complete censuses of 0.1-1.0 ha plots for plants and their insect herbivores. This sampling requires access to forest canopy, canopy cranes, mobile platforms mounted on trucks (heavy-duty ‘cherry pickers’) or cutting down the forest. Whilst the latter does not sound very conservation-minded, there are many opportunities to conduct such sampling without contributing to deforestation, especially when working with indigenous peoples practising slash and burn agriculture.

With these new datasets providing snapshots of plant-herbivore food webs from entire forest plots, we can consider new types of analyses, including more rigorous comparisons between tropical and temperate zone forests.

What would you say are your most important findings so far?

Our analyses demonstrate that global patterns of diversity can be explained simply by parallel patterns of plant diversity for some, but not all insect taxa. For instance, leaf-mining insects chewing tunnels inside leaf blades, faithfully follow plant diversity. An average European tree species hosts a similar number of leaf miners with similar host specialisation to a tropical tree.

In contrast, ants behave differently and we should have many more ant species in Europe, at least according to predictions by models using plant diversity. Interestingly, plants determine insect herbivore diversity through the variety of resources they provide. Meanwhile, insect herbivores may determine how many plant species can coexist by keeping them from outcompeting one another. It is a real Mexican standoff between plants and herbivores in tropical forests.

What do you still need to achieve before the end of the project?

We are in the middle of a detailed sampling using the brand-new canopy crane that we built in Papua New Guinea, which is fully operational and open for researchers all over the world.

Despite the present travel restrictions, local staff are using the crane fulltime to document the entire plant-herbivore food web for 0.8 ha of lowland rainforest within its perimeter. In our European labs, we are also developing better analytical methods for the comparison of tropical and temperate food webs. This is not an easy task as the food webs differ in a variety of aspects, from the diversity and abundance of plants and herbivores to phylogenetic diversity and patterns of trophic interactions.

How do you think the project can contribute to the preservation of biodiversity in a context where tropical
preservation of biodiversity, in a context where tropical forests have never been so threatened and political action is desperately needed?

We cannot successfully protect systems that we do not understand, so any progress in ecological knowledge has some relevance to conservation. However, I see a more immediate importance of our research for conservation in the way we are doing the research, rather than in the results it brings.

At all three tropical locations (Papua New Guinea, Cameroon and Panama), we involve local researchers, technicians and students. In many cases this is the first time they experience ‘real’ research. ‘Capacity building’ is somewhat of a cliché promised in almost all research grants for rainforest research, but it can only be accomplished through long-term training of students and researchers.

Equally, local research capacity is essential for successful conservation. International conservation organisations have traditionally had a lower success rate in the tropics as they tended to work there as cultural implants, often unaccepted by local society, though this has improved markedly over recent years. But without such acceptance, especially within the indigenous academic community, tropical conservation is impossible. Our work in Papua New Guinea, on the other hand, closely involved indigenous communities who own the forest lands. They decide about their conservation or logging.

It is not widely recognised, but indigenous peoples are not born conservationists. They need an income stream to pay for lost income that could result from conservation efforts in comparison with converting lands to agricultural or forestry projects. Our research provides such income and reflects many successful cooperation initiatives between international conservation organisations and local communities. Our research infrastructure, such as the canopy crane and the permanent forest dynamics plot, attract other research teams. In this way, our research is directly responsible for maintaining two rainforest conservation areas, and hopefully they could inspire other researchers elsewhere in the tropics.

Keywords

Diversity6continents, tropical forests, insects, plants, food web

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