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No Rest for the Curious

Our organization spent the last 25 years cataloguing the biodiversity of the Nectandra Cloud Forest. After the initial land purchase for conservation, we immediately launched a (continuing) survey of its flora and fauna. In the least, we should know what is being conserved and protected!

To the extent feasible, we planned to enumerate/identify the plants and animal species present within the boundary of the 158 Ha (370 A) reserve. As steward of a piece of tropical cloud forest, entirely forested, at 1100 m (3600 ft) elevation on the wetter Atlantic slope of Costa Rica, we were very aware that the reserve is located in a hotspot within the world's biodiversity hotspot. The inventory goal was straightforward. Its execution, however, has been anything but uncomplicated.

Our first target — vascular plants — to be surveyed was a no brainer. They are big and do not move. No need for traps or foot chase. To get a rough idea of the scale of our task, we explored a "virtual" method to count the trees. Remember, drones were not yet available in early 2000's. Fortunately, at that time, LANDSAT (NASA/USGS joint program) began to make available black and white, digital satellite photographs of the entire globe, including our area. In addition, we downloaded simple software (publically accessible from the Jet Propulsion Laboratory) used to study lunar geologic features. We analyzed the trees in the satellite photos at various "tilt" angles to reveal the shadows of each individual tree, thereby rendering each tree countable manually. The result yielded a *very* rough estimate of ≥5000 large canopy trees (lower limit) in 104 Ha of the reserve. Of course, there would be many more understory trees invisible to the satellite at 700 km. This result forewarned us of the scale of our task.

To get an actual number and species of trees on the ground took much more physical labor hacking through the thick jungle. We randomly marked off 30 investigational plots, 10m x 20m each, totaling 0.6 Ha. Within each plot, we counted, tagged and identified every tree (excluding all epiphytes), defined as plants ≥5 cm diameter in those parcels, with the help of botanical taxonomist Gerardo Rivera. Many months later, the tallied results showed 889 trees of 126 species in those 30 plots .

I should digress here to explain that I was an untrained field biologist at that point, who had only a general understanding of high biodiversity. Everybody knows that high biodiversity means higher number of species. But what other significance? As I started to analyze the data, a gradual, vague sense of eagerness started to seep in. It was the same sensation I had staring at a photo print being developed in the dark room. Just as the grains of silver halides in photos, the numbers and names of trees on the pages before me started to form a faint image, then suddenly popped into a realization with utter clarity.

First, what I expected was borne out. The density of trees at Nectandra (1500 tree/Ha) was approximately 10-100 fold higher compared to non-tropical forests, (depending on climate and tree types roughly 20 -200 trees/Ha). The Nectandra species density, 126 species in 0.6 Ha, was also much, much higher, compared to temperate pine forest where about half a dozen species dominate. For every tree visible on the LANDSAT photo, there were actually 30 times that under the canopy.

What excited me most was the new information gleaned from those numbers — 60% of the plant species appeared only once among the 30 plots and another 30% of species appeared twice. This was what biologist Adrian Forsyth (*Tropical Nature*) had in mind: "In the tropical forest, the rare organisms are common, and the common are rare". *This is the essence of high biodiversity*. No species dominate, attesting to the fierce competition for each survivor to persist. Every square meter of a cloud forest is unique.

From this survey, we now know the areas of mature (i.e. tallest, largest trees) vs secondary (pioneer species) forest, what animals are likely there from the presence of their favorite fruit trees, etc. A complete surprise was the richness of the iconic tree ferns (3 genera with 17 species) at Nectandra. These ferns are currently protected in Costa Rica under international CITES and national regulations.

In the intervening years small mammals, reptiles, amphibians, ferns, lichens, mosses, liverworts, hornworts were added to the growing list of surveyed organisms, from work contributed by guest researchers, interns or volunteers. Remaining on our list are two glaringly missing groups, potentially millions of insects and thousands orchids species. We were simply

overwhelmed by their sheer number known to be in Costa Rica.

Imagine our delight to have a group of ten entomologists (see News Jan 2023) dropping in on us two years ago! Since that explorative visit, Nectandra joined their network of survey sites for flies and wasps.

We are still reeling from what they have learned and uncovered since. The diversity of the parasitic flies (Phoridea) and wasps (Braconidea) at Nectandra is not just high, but "crazy" high, according to Brian Brown (the author of following article). It will be sometime yet before they have all the results of the still ongoing survey.

In the meantime, I will leave it to Brian Brown and Michael Sharkey to explain the dilemma when faced with such hyperdiversity.

—— *Evelyne Lennette* ——

Nectandra Insect Survey

Brian Brown, Natural History Museum of Los Angeles
Michael Sharkey, Univ. of Kentucky Hymenoptera Institute

Insects are the most biodiverse group of fauna on the planet; even plant diversity pales in comparison. We humans underestimate and undervalue insects because of their small size. Insects are our main competitors for food and are significant vectors of lethal pathogens, for us and other living things. They have immense impacts on the environment, more than larger fauna. At the same time, as the dominant biologic link among life forms, they are irreplaceable parts of our biosphere.

We also underappreciate their great beauty and the incredibly intricate lifestyles and behaviors they display. (Fig.1 & 2).

Fig. 1 *Xanionotum sp.,* a genus of parasitoid flies ~2-5 mm in size that prey on tropical ants through various modes of ant decapitation.

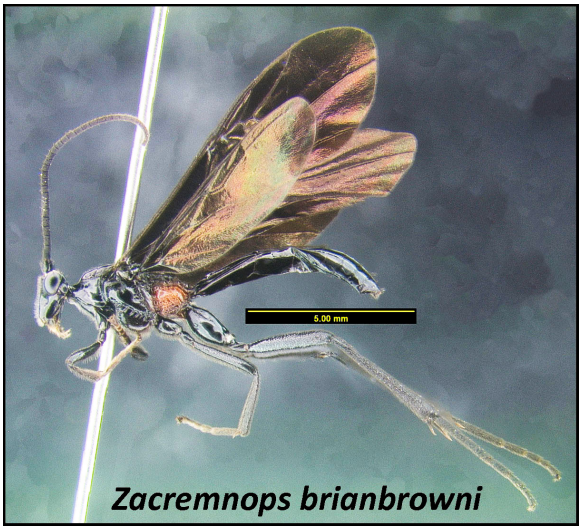

Fig 2. *Zacremnops brianbrowni*, a parasitoid wasp named after one of the authors.

We do not yet have a good estimate of the number of the world's insect species. Most recent studies indicate that there are 5 to 10 million species of insects in the world. However, work by Dr. Terry Erwin of the Smithsonian Institute in the 1970-80's suggested close to 30 millions. The careful estimation from our own work with traps (24/7 for one year) in Costa Rica is at 30 millions, just as Erwin hypothesized 50 years ago.

Most insects are small species that are classified in scarcely known groups, e.g. Cecidomyiidae, Phoridae, Chalcidoidea, Ichneumonoidea etc. Because they are little known, they lack common names, although they outnumber birds and other larger animals by orders of magnitude. For instance, in an informal survey done at the Natural History Museum of Los Angeles County, we asked museum visitors to estimate the number of species of birds in the world. Their answers varied widely. We then gave them the real answer (about 10,000 species), and asked how many flies there were in the world. Their guesses did not even approach the number of flies actually named (about 160,000 species).

Thus, it may be difficult for some to understand why we specialize in such narrow groups of insects. For instance, one of us (Brian) is working on the Phoridae, the small parasitic flies that account for about 4,500 named species worldwide. Mike estimates that their number to be closer to 800,000 phorid flies, a number that dwarfs all other known groups of organisms. Similarly, the braconid wasps that Mike works on consist of a huge radiation of hundreds of thousands of species as well.

Like other people, entomologists are prone to denial when they face impossible odds. Most entomologists tend to think that such hyperdiverse groups, which we call dark taxa, will never be completely classified. They

are simply too numerous for traditional techniques. We on the other hand are among the few scientists in the world who are interested in taking on this diversity challenge, by using new technology called DNA barcoding to characterize our species. Identifications that traditionally require many hours or days per specimen, can now be done almost instantly by sequencing the DNA of the gene of cytochrome oxidase 1 (658 base pairs of COI). It codes for one of the important respiratory enzymes in the mitochondria of cells. It has just the right amount of variation in many animals (scientists use other genes for plants and fungi) to allow differentiation of one species from another. This technique will allow identification down to the species level for most fauna specimens and to detect previously unknown groups.

Although there are many biologists using DNA sequencing (barcoding) to monitor species throughout the world, only a few are doing what we propose: a rapid, first-pass inventory. Rather than documenting and noting minute details about insects, one organism at a time, our plan is to rapidly barcode through collections of specimens, batch-wise, using a combination of DNA sequences, photography, and notations of a few key morphological characters.

The end result will be a large data bank, each specimen labeled with a genus/species name (or a unique specimen number for new organisms), their respective DNA sequences given, and their photographs attached. This public information bank will be accessible to other biologists for additional molecular or biological workup.

Naturally, not everyone feels that this is the best approach. The controversy concerns the unavailability of traditionally obtainable biological information associated with each species described. However, in view of the tsunami of unknown species still to be studied and the concomitant global biodiversity destruction, we can no longer wait. We must adopt practical large-scale faunal surveys.

Our goal is to have comparable surveys across Costa Rica, especially in other cloud forest areas, to let us understand how biodiversity changes across the relatively small distances of Costa Rica. In particular, our colleague Dan Janzen has sent many thousands of phorid flies and braconid wasps to the laboratories of the Canadian Center for Biodiversity Genomics for sequencing. These include a site called "Derrumbe", which is a cloud forest on Volcan Cacao, and which can serve as our first site to compare with Nectandra.

By doing this type of large-scale inventory we will gain an unprecedented understanding of Costa Rican cloud forest and other habitats. Thanks to the forward-looking vision of the Nectandra Institute, our project, once only a dream, can now become a reality. We are looking forward to your support.

Recent Sightings

The greatest joy in living in the cloud forest is the unceasing parade of new faunal or floral encounters. For example, though supposedly common, the sheep frog in the photo below was seen at Nectandra for the first time this year. It hides and lives underground in burrows, feeding on subterranean ants or termites, emerging after dark only during mating season. It surfaced from its deep burrows this year after days of torrential rain.

Photo - *Hypopachys variolosus,* body inflated in a defensive position while it was being photographed.

Two orchids were among the "new" to Nectandra sightings in 2023. For whatever reasons, they only bloomed this year for the first time in decades, rendering them finally visible. Our garden staff must have walked by these plants thousands of time during this period.

Photo left – Orchid *Warrea costaricensis*
Photo right – Orchid *Arpophyllum giganteum*

Year 2023 Community networking

It's been quite a year for Nectandra Institute's education and communal outreach programs.

At the formal part of the 15th annual celebration of the New Culture of Water Month (above), members of more than a dozen communities and water associations with Nectrandra Institute's ecoloans attended the presentations.

It was followed by the tree transplantation session at the first Eco-loan property of Angeles Norte, now in its 15th year of reforestation.

Below. Volunteers were preparing a new site for large water tank to service the community of Angeles Norte. They are planting *Chrysopogon zizanioides*, a grass and member of the sorghum family. Its long (≥4 m, 12ft) exclusively downward roots makes it ideal for controlling soil erosion and stabilizing steep banks.