ISSN 2953-741X
Funga Latina **1** (2023) V1A1 https://doi.org/10.5281/zenodo.10214873

The power of teaming up: three stories of directed research in mycology

Carlos Rojas[1] and Robin G. Doss[1]

[1] Maialu S.A., San José de Atenas, 20506-Costa Rica.

E-mail: rojas_carlos@outlook.com

Received: 30 September 2023
Accepted for publication: 21 October 2023
Published: 8 December 2023
Editor: Nataly Gómez-Montoya

Abstract: Between 2009 and 2011, we came to Costa Rica as part of an educational program established in the country intended to give American students an opportunity to learn about sustainability in the tropics. We were given the task to coordinate three teams of students and carry out, in only one week each time, a quick field project focused on documenting ecological aspects of fungi that could be used for conservation purposes later on. Herein, we provide more details about these experiences and ellaborate on the consequences of what we did. Our effort may have even had greater impact on us,than the impact we had on the students that we worked with.

Keywords: Carara National Park, Costa Rica, education, Grecia Forest Reserve, mycoliteracy.

It was April 4, 2009, and we were at the University of the Ozarks, in Clarksville, Arkansas, in the United States. We were communicating our latest scientific findings in the 93rd annual meeting of the Arkansas Academy of Sciences. After a long day at the meeting, we noticed an email from a local scientist in Costa Rica inviting us to travel to this tropical country during the summer of that year. Wow! What a nice idea! We were going to be educating American students abroad. Of course, we did not turn down the opportunity and just a few months later, we flew down to Central America.

In a local Costa Rican town called Atenas, we were given the task to organize a rapid thematic training that could provide students with a more in-depth experience on biological research. They called this activity *Directed Research* or *DR* for short. We had to choose both a biological group and an ecological focus before we could organize the project with the students. We chose fungi, a taxonomic group both of us had some experience with, and for the ecological focus we selected the issue of edge effect, or how the border of the forest has an impact on a biological group. That way, our original plan was to study edge effect on tropical fungi! The idea sounded good since there was not a lot of local information on the topic, but it also sounded challenging because we had to carry out this project in an enigmatic national park called Carara, in the Central Pacific region.

We chose the week of the 22-28 of June of 2009 (boreal summer, vacation time in USA!) to visit the area and conduct several projects along with students. Things went so well, that with a second group of students, we revisited Carara one month later during the week between July 27 and August 2. These are the first two stories we would like to talk about. After the second experience and the return to the United States, we got busy with life decisions which even included a choice to move to Costa Rica. Finally, almost two years later, during the week of the 25-31 of July of 2011, we got a chance to repeat the same experience with a third group of students. That time, however, we were going to study fungi in native and non-native forest patches in the Grecia Forest Reserve, a location in the foothills of the great Poás Volcano.

The three stories we are about to relate ended up representing much more that simple memories of our academic activities. We still sit down and remember details about the field trips, the people, and the professional experience we obtained with them. "¿Do you remember Carara? ¿Do you remember Grecia?" We would like to think that we, as mentors, were positive examples for the younger generation of students that we interacted with, but truly speaking, these experiences also gave us much more than memories.

The wonderful thing is that the information we obtained on fungi, that never became published, also tells a story of great importance. Because unpublished data is almost equal to science that never took place, and because the role of fungi on Earth has historically been underestimated. For those reasons, parallel to the first anecdotes we will show some scientific data as well. We think is important to finally show what we saw at that time.

Here we go…

Number one – The backside of Carara National Park

Carara, in the pre-Columbian Huetar language, means *river of alligators* and was a term used for the area alongside the Tárcoles River in the Central Pacific of Costa Rica. This general area is famous today for a population of American crocodiles with adults that can reach almost five meters in length and close to 600 kilograms in weight. These crocodiles are huge! The name Carara was used in 1978 to protect 5200 hectares in the same location and the land became a national park in 1998.

We were a group of six people, and our task was to study different aspects of the edge effect-fungi relationship on the backside of the Carara National Park (see Fig. 1 for a geographical reference). Before we established our camp in a small town called El Sur, with barely basic accommodations, the students had a quick one-day workshop on fungi. We talked about types, colors, shapes, edibility and so on. We also mentioned scientific names and ecological functions. We knew it was going to be very limited what anyone could absorb in such a short time, but we tried to come up with a plan for the field days.

On paper, we were going to spend the next week obtaining data to address the following issues: 1) edge effects on rare vs. abundant macrofungi, 2) edge effect on fungal diversity, 3) abundance of wood-decomposing fungi vs. leaf-decomposing fungi, 4) the impact of forest edge on fungal genera and 5) the effects of sampling effort on diversity indicators using macrofungi. We knew beforehand that one week was not enough for a robust sampling methodology that could end up in a scientific publication, but we recognized that one week could be enough for stimulating the minds of students and exposing them to the diversity and functions of fungi in nature.

In the end, we discovered together that rarity, as an indicator of good habitats, increased as we moved inside of the forest (Table 1) and that the diversity of fungi increased slightly in the same manner

(Table 2). We also learned that the number of leaf decomposing fungi did not really increase or decrease as we moved into the forest, but that the number of wood decomposers (but also the availability of substrates) was clearly higher as we moved away from the edge (Fig. 2). Similarly, we learned that *Marasmius* fungi, a type of umbrella-like mushrooms, were more common at the border and that *Xylaria* fungi, the famous dead man´s fingers, preferred the internal parts of the forest (Fig. 3). Finally, we learned that triplicating our unit of effort in the field increased our diversity results by 43% in the forest edge and by 28% in the most internal part of the forest. In short, there were differences between the fungi at the forest edge and the fungi inside of the forest and the effort used to study fungi was important.

We thought it was impressive that just few days before the field trip took place, most students had no idea of fungal types and functions and that by the end of the week working in the field, they all had a pretty good idea of the basic biology of the group. The idea of the *DR* ended up being an interesting one to pursue since we had some funds available to support the one-week field trip. It was worth attempting to obtain scientific data as a team in a short period. As expected, information built up quickly in just one week of intensive team-based work.

Of course, we did much more than field work (Fig. 4), but besides a lot of enjoyable activities, most importantly, we teamed up and learned from each other. We also practiced, in our self-imposed collectivity, how to increase tolerance for other people´s opinions and how to address personal differences by means of dialogue. We were quickly becoming a network of ideas and actions, that albeit rough at first, was rapidly getting refined. We were almost becoming a biological entity.

Figure 1. Approximate outline of the Carara National Park (right) and the Grecia Forest Reserve (top left) and the general location of both places in Costa Rica (bottom left). The exact location where the groups of students were taken is also shown.

Table 1. Counts of macrofungi associated with distances from the border of the backside of Carara National Park in June 2009, arranged in categories of abundance.

	Abundance Category				
Distance	**Abundant**	**Common**	**Occasional**	**Rare**	**Total**
0 m	12	16	0	0	28
40 m	11	18	0	0	29
80 m	11	7	16	0	34
120 m	12	10	13	0	35

Table 2. Sørensen and Shannon-Wiener Index values for fungal records associated with distances from the border of the backside of Carara National Park in June 2009.

Distance (m)	**0**	**40**	**80**	**120**
0	1	0.73	0.58	0.66
40		1	0.63	0.75
80			1	0.78
120				1
Shannon Diversity Index	2.89	2.96	3.12	3.11

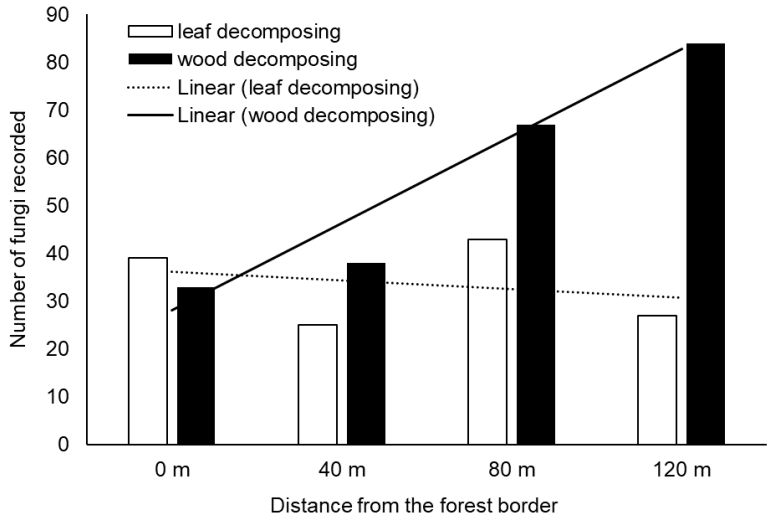

Figure 2. Number of leaf decomposer and wood decomposer fungi associated with distances from the border of the backside of Carara National Park in June 2009.

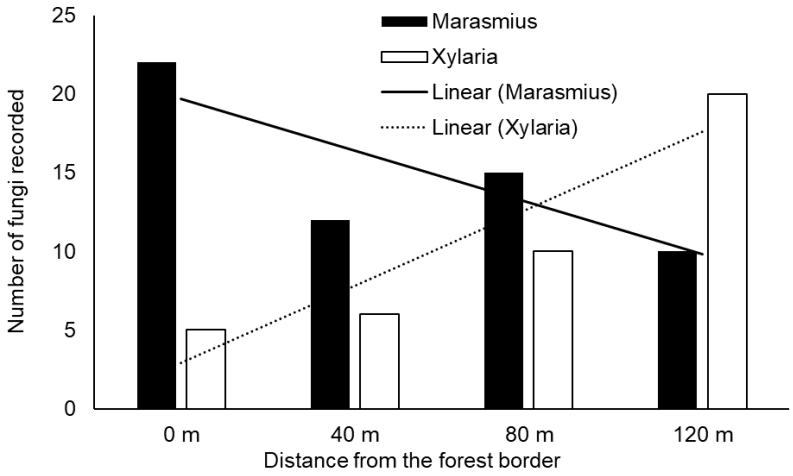

Figure 3. Number of fungi from the genera *Marasmius* and *Xylaria* associated with distances from the border of the backside of Carara National Park in June 2009.

Figure 4. Images from the backside of Carara National Park in 2009. As observed, for mycoliteracy purposes the most important aspect is to keep the interest of the group on fungi. As most field biologist know, simple accommodation is always fine.

Number two – The frontside of Carara National Park

We were so thrilled with the first experience that we wanted more, and just one month later, with a second group of students, we went back to Carara National Park. This time though, we did not have our base in a small-town unknown by most people in Costa Rica. This time we decided to spend our week in the well-known community of Tárcoles.

This town is home to several families and cooperatives of fishermen and is a synonym of pollution for Costa Rica´s Central Valley residents. Due to its proximity to the Tárcoles River, one of the most polluted in Central America, the community of Tárcoles suffers from a lack of economic opportunities. Being so close to the frontside of the Carara National Park, this town should have been the target of the economic impact of tourism. Ironically, its bad environmental reputation did not allow such progress to occur.

Using the same scheme that we used in El Sur; we planned on studying fungi on the frontside of Carara, the most impacted by human activity. We were going to focus on: 1) the effect of the forest edge on the distribution and abundance of fungi, 2) the impacts of the forest edge on the abundance of *Marasmius* and *Xylaria* fungi, two interesting case studies, 3) the relationship between microenvironmental factors and fungal diversity, and 4) the contrast in diversity using data from the back and the frontside of Carara National Park. Our plan seemed feasible and the only thing we had to do was to collect the data and analyze it.

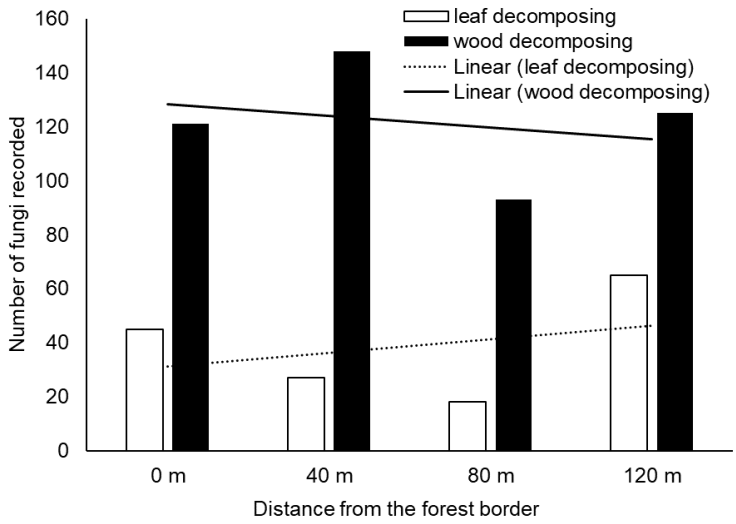

Figure 5. Number of leaf decomposer and wood decomposer fungi associated with distances from the border of the frontside of Carara National Park in July 2009.

This time, we learned, collectively, that on the frontside of the protected area the abundance of either leaf- or wood decomposers is similar between the forest edge and the internal parts of the forest (Fig. 5) and that the abundance of *Marasmius* and *Xylaria* fungi was consistent with the previous observations on the backside (Fig. 6). We also learned that the number of fungal genera was correlated with the depth of the leaf layer on the forest floor and that both values increased from the forest edge to

the internal parts of the forest (Fig. 7). Finally, we concluded that even though the diversity values of fungal communities increased from the forest edge into the forest, the communities on the backside of Carara were always more diverse than those on the frontside of the park (Fig. 8).

In a similar way to the experience that we lived one month before, we constructed knowledge while playing and having fun (Figure 9). Clearly, group bonding by means of working together towards achieving collective goals, in this case scientific ones, allowed the group to obtain data and enjoy the process of learning about tropical fungi. The opportunity to spend so much time together also allowed the group to gain cohesiveness and a sense of unity that paid off sometime later when we had to present the results of our work to the park rangers and administrators of the national park.

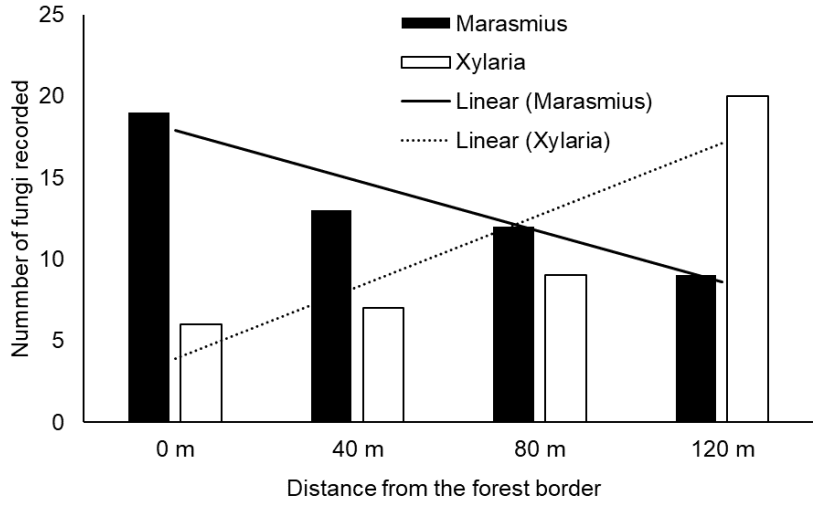

Figure 6. Number of fungi from the genera *Marasmius* and *Xylaria* associated with distances from the border of the frontside of Carara National Park in July 2009.

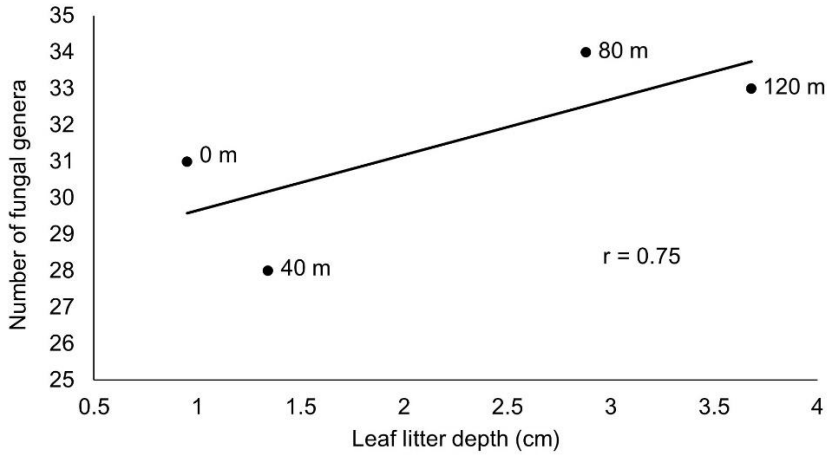

Figure 7. Correlation between leaf litter depth and number of fungal genera associated with distances from the border of the frontside of Carara National Park in July 2009.

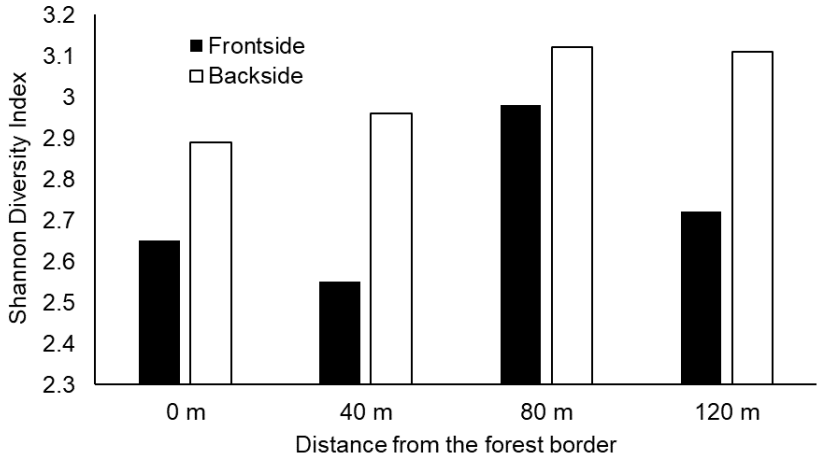

Figure 8. Distribution of the Shannon Diversity Index in relation with distance from the forest edge for both the frontside and the backside of the Carara National Park as determined in June-July 2009.

Figure 9. Group bonding resulted in good social dynamics for obtaining scientific data (see the second author obtaining hemispherical pictures for analysing canopy openness in the top center image) in the frontside of Carara, in July 2009 ¿Who said scientific work had to be boring?

Number three – Grecia Forest Reserve

We had to wait 103 weeks before we could have our last *DR* experience on fungi in Costa Rica. Almost two years after our previous experience, a one-week intensive training sounded very feasible

because we knew the dynamics and the logistics of the process. This time, though, we had thought of another location for the activity. One that sounded much more appropriate to work on fungi.

The Grecia Forest Reserve is a protected area in the southern foothills of the Poás Volcano. This area encompasses about 2600 hectares of premontane forests containing oak and wild avocado trees. In 1979, 40 of the original hectares were reforested with non-native pine, cypress, and eucalyptus trees by kids from nearby communities and the whole area became known as "Bosque del Niño" or Child´s Forest.

In this location, we had to camp and improvise a research laboratory in an open dining hall, but we did not have to worry about food because someone else would cook for us. What a luxury! Because of that, we also were able to focus our efforts on documenting carbon stocks and plant diversity in distinct forest types. However, with fungi we decided to study 1) the relationship of reproductive tissue to biomass in fungi, 2) the productivity of fungal forms based on forest type, and 3) the diversity of mycorrhizal fungi in native vs. non-native vegetation forest patches as well.

One more time, we worked intensively for the entire week. This time in tougher weather conditions than the previous experiences. However, the wonderful forest in Grecia made it easier to bare. As some people know, waking up after sleeping in a tent, just to see, hear, and smell a mountain forest after light rain overnight, is a magical experience. And for us, knowing that during the day we were going to do something we liked, simply did not leave room for unpleasant feelings.

After that week, we were able to provide some data to the issues we studied. Once more, as a team, we learned that fungi in native forest patches allocated less resources to the production of reproductive tissue and more to the production of biomass than in non-native forests (Fig. 10) and that such pattern was more evident in mycorrhizal fungi (Fig. 11). We also learned that fungi grew bigger when native trees were present (Fig. 12) and that, in general, there were more mycorrhizal fungi in the areas dominated by native vegetation (Fig. 13). Finally, we learned that the overall diversity of fungi was larger in the areas with native vegetation.

When we connected the fungal data with the forest assessment that we also carried out, we realized that there were interesting aspects to study in more detail. Perhaps the fungi in the Child´s forest, a large percentage of which were mycorrhizal, could show a quicker response to climate data than a fungal population in an area with less mycorrhizal trees. In the end, in a forest with an abundance of mycorrhizal fungi – large mushrooms for the most part – a lot of carbon had already transferred from the trees onto to the fungal networks and ultimately formed the dozens of mushrooms we saw. Perhaps, that carbon was great enough, that we could estimate it…

This time, our relationship with the students became almost philosophical (Figure 14). Perhaps the magical forest had something to do with that. In short, we realized that we were in a beautiful place that somehow was showing its fragility to us. And we were looking at numbers and scientific names which almost felt like representing our less acknowledged neighbours in nature. We were feeling that it was our responsibility to take care, in a protective manner, of the forest that we were in. Our words would be the ones giving voice to nature. Fungi and their ecology taught us that resilience, vulnerability, and adaptation, all those words we had heard from the climate change jargon, were the continuous playwriters in the theatre of modern nature.

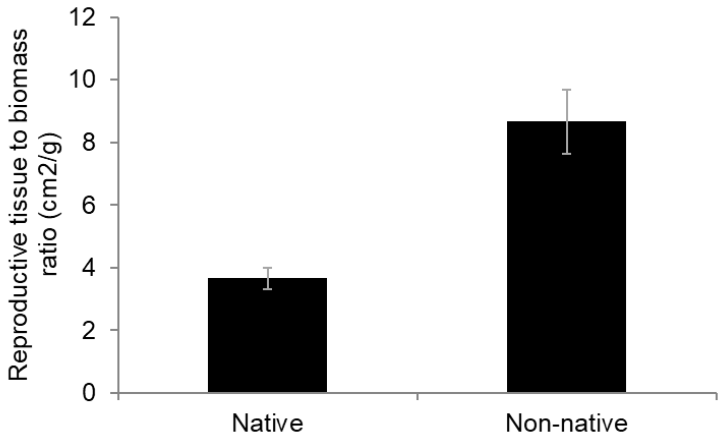

Figure 10. Mean ratio (and standard deviation) of the area represented by the reproductive tissue and the mass represented by the weight of fungi in native (mainly oak) and non-native (mainly pine and cypress) forest in the Grecia Forest Reserve during July 2011.

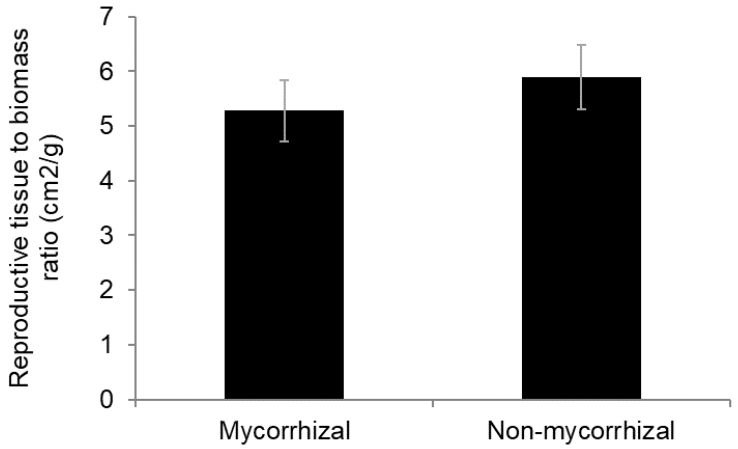

Figure 11. Mean ratio (and standard deviation) of the area represented by the reproductive tissue and the mass represented by the weight of fungi for mycorrhizal and non-mycorrhizal fungi in the Grecia Forest Reserve during July 2011.

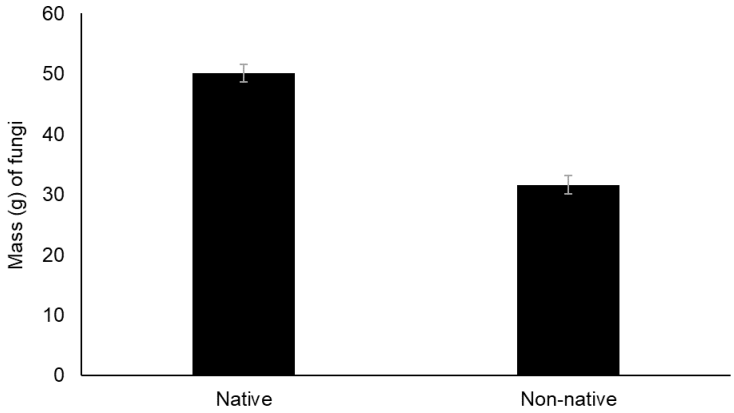

Figure 12. Mean mass (weight) of the fungi recorded in native and non-native forest patches in the Grecia Forest Reserve during July 2011.

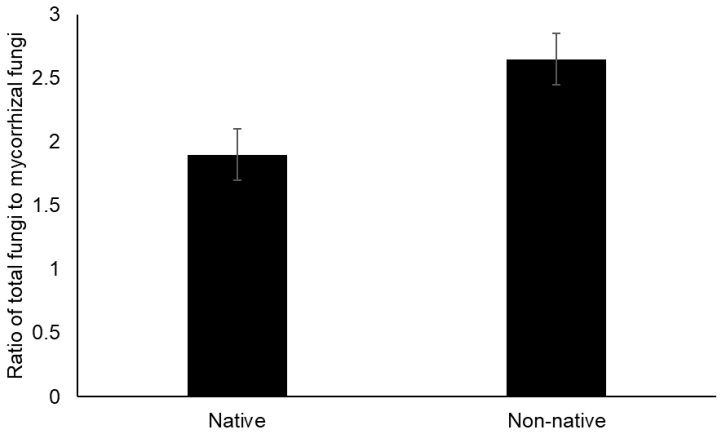

Figure 13. Ratio of total fungi to mycorrhizal fungi in native and non-native forest patches in the Grecia Forest Reserve during July 2011.

What can we get from all three stories?

The important message here is that we are in moment of global history when doing something – executing plans – is highly relevant. Thinking, planning and organizing is extremely valuable, of course, but we can lose precious time documenting our planet if we procrastinate on those stages. We don´t have to be scientists to help science move forward in the same way we all contribute to the conservation of cultural heritage by simply being ourselves. It's all about taking action.

The three stories we included herein show that defining priorities and focusing on them can have profound impacts on the participants of those processes. We can´t speak for the students since, in the end, all of them went back home and returned to their normal life. We don´t know what happened to them even though we have always wished that our effort made an impact on their professional careers. However, we know what happened to ourselves.

Figure 14. Improvised kitchen and dining area (left) and team of participants (right) of the expedition to the Grecia Forest Reserve in July 2011. The cohesiveness of the team can be seen in the fact that our cook and one very helpful ranger are present in the picture.

In the decade that followed these stories, we ended up proposing formal scientific projects, obtaining funds, and executing different initiatives in which fungi were always present. We carried out field assessments trying to understand the effect of climate on fungal populations and on forest dynamics. We tried to assemble a picture of how young adults in Central America perceived fungal resources and we also attempted to understand how fungi in soils could contribute to soil erosion control and to the quality of solid biofertilizers. We ended up publishing a scientific opinion article in which we called the preference of local scientist for studying "anything else but the fungal-forest relationship" a *denial of imperative research*. How can´t they see what we see?

We want to think that we have been doing something.

Modern education sees itself as a dual and active process in which both teachers and students can learn from each other. For us, such a paradigm could be real, and team-based education could be one example of a promoting space. It does not matter who the teammates are, or where they come from, or even what age and formal training they have. Aren´t we all teammates in our own families despite all visible differences? Teaming up is a powerful strategy to achieving common goals and it is an extraordinary approach to balancing divergent and convergent thinking. Modern companies know this very well since there must be a balance between creativity and efficiency. Could we incorporate these techniques a little more in our routinary professional or civil duties?

Nature can show us the paths of sustainability and survival of our species. From such a giant picture, fungi can teach us that networking – teaming up as we defined it herein – is the ultimate mechanism of energy modulation. Ecosystems work, adapt and change – evolve – by means of constantly assessing energy dynamics. Fungi represent one of the groups of organisms that transports, modulates, and expedites energy flows in those ecosystems; and the visible forms of fungi, the reproductive structures, represent an evident form of energy temporarily stored. And all of that takes place by means of responding to signals within the ecosystem networks they form. In other words, fungi sense and then respond, almost like listening first in order to provide an adequate answer.

When we met with other scientists at the 93rd annual meeting of the Arkansas Academy of Sciences, back in 2009, we did so because we wanted to communicate the results of our research. We did not notice, at that time, that we were part of a system that relies on networking, on teaming up, for validating scientific results. Could it be that scientists realized, a while ago, that just like fungi, we can transport, modulate, and expedite informational flows by means of responding to signals within the networks we form? That idea sounds nice, but we all know that the origin of scientific meetings certainly has a much more accurate origin, historically speaking.

It is just that sometimes, there is no distinction between fictional and non-fictional reasoning when thinking about fungi. After all, once the doors of their magical world are opened, it is hard not to see a reality without the multiple lessons that we can learn from such organisms.