Amigos Newsletter

No. 90, Dec 2018

Organization for Tropical Studies

Wilson Botanical Garden

Las Cruces Research Station

Apdo. 73-8257 San Vito, Coto Brus, COSTA RICA

Who We Are

The Las Cruces Biological Station is one of three field stations owned and operated by the Organization for Tropical Studies (OTS) in Costa Rica. The station was acquired in 1973 and, along with the Wilson Botanical Garden, offers natural history visitors and researchers alike an extraordinary place to visit and conduct research.

Far from the noise and bustle of the country's capital city San José, Las Cruces is located in the remote southeastern corner of the country between Corcovado National Park on the Osa Peninsula, and the enormous La Amistad International Biosphere Reserve (472,000 hectares) that spans south-central Costa Rica and western Panama. In 1983, UNESCO declared Las Cruces and the Wilson Botanical Garden part of the Biosphere Reserve due to its incredible diversity and proximity to La Amistad.

The Wilson Botanical Garden, founded in 1962 by Catherine and Robert Wilson, is arguably the most important botanical garden in Central America and a "must see" stop on the itineraries of plant lovers, birders, and other natural history groups. It is famous for its worldwide collection of tropical plants that include palms, aroids, bromeliads, gingers, marantas, heliconias, and ferns. More than 3,000 exotic species of plants can be found in the 10-hectare (~ 25-acre) garden, including one of the largest collections of palms in the world.

There is an incredible diversity of animals that inhabit the Las Cruces reserve, and the forest fragments in the immediate surrounding area. The bird list has registered 410 species; close to half the number of birds found in all of Costa Rica. There are also more than 100 species of mammals, of which 60 are bats. Some of the more commonly sighted mammals include agoutis, white-faced capuchin monkeys, kinkajous, olingos, and tayras. Reptiles and amphibians also thrive in this moist, cloud-laden habitat and there is an impressive diversity of insects, and in particular moths and butterflies.

Las Cruces protects more than 200 hectares of primary forest (home to some 2,000 native plant species) and ~150 additional hectares that are in various stages of forest recovery. The reserve is surrounded by a mosaic of mixed-use agricultural fields and forest patches, and it is this fragmented setting that makes Las Cruces an ideal place to study the effects of forest fragmentation and isolation on animal and plant communities. The landscape surrounding Las Cruces is also ideally suited for research on biological corridors and restoration ecology; key fields of research that are of ever increasing importance. Part of our mission at Las Cruces is to continue to purchase land for reforestation and, in doing so, expand our protected areas and connect some of the isolated forest fragments around the station. For further information on this campaign please visit the Las Cruces website.

At approximately 1,200 meters elevation (3,900 feet), the prevailing temperatures at Las Cruces are cooler than one might expect. Temperatures range from 21-26 °C (70-80 °F) during the day and 15-21 °C (low 60's) at night. Mean annual rainfall is ~4,000 mm (157 inches)! The dry season runs from January – March, and the rainy season from May – November. Most visitors and researchers come during the dry season.

The station is well known for its visitor-friendly amenities: comfortable private sleeping quarters, excellent meals, knowledgeable and enthusiastic staff, and a well-maintained network of paths and trails. The nearest town is San Vito, the municipal capital of Coto Brus county. It was founded by Italian immigrants in the 1950's and to this day they have a strong presence in the community. For example, a Dante Alighieri Italian-Costa Rican Community Center provides Italian language instruction and Coto Brus is the only county in Costa Rica where Italian forms part of the elementary curriculum! But enough said here! We hope that you will be inspired to come and experience firsthand the splendid tropical diversity of the Las Cruces Biological Station and Wilson Botanical Garden!

Please visit the Las Cruces website at http://www.tropicalstudies.org/lascruces for more information or contact us directly by email at lcruces@tropicalstudies.org or telephone at: +506 2773-4004. Postal mail can be sent to: Estación Biológica Las Cruces/Jardín Botánico Wilson; Apdo. 73-8257; San Vito de Coto Brus, Puntarenas; Costa Rica.

Reservations can also be made by contacting the OTS office in San José by email: threepaths.reservaciones@tropicalstudies.org or by telephone +506 2524-0607.

The North American OTS office is located at Duke University, telephone: +1 (919) 684-5774 or email: ots@tropicalstudies.org

The Organization for Tropical Studies is a nonprofit consortium of universities and research institutions in the U.S., Costa Rica, Peru, Mexico, South Africa, and Australia.

Founded in 1963, OTS is dedicated to providing leadership in education, research and the responsible use of natural resources in the tropics. To this end, OTS offers graduate, undergraduate and professional education, facilitates research, participates in conservation activities, conducts environmental education programs and maintains three fields stations in Costa Rica: La Selva Biological Station in the Atlantic lowland rain forest; Palo Verde Biological Station in the Pacific deciduous dry forest; and Las Cruces Biological Station in the premontane cloud forest near the Panamanian border.

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Front Cover: Detail of the Wilson Botanical Garden: Painting by Deirdre Hyde.

Back Cover: Bromeliad Hill: Painting by Deirdre Hyde.

Editorial Committee: Rebecca Cole and Carl Schmitt

Director's Keys and Notes

Las Cruces chef, Edier Monge Navarro

Rebecca Cole / rebecca.cole@tropicalstudies.org

One of the best things about mealtimes at Las Cruces, besides the great food, is the company you meet. During the high seasons, the dining hall becomes a crossroads for scientists, nature lovers, students, artists, writers, volunteers, and an eclectic assortment of folk from the local community. The guest sitting next to you might turn out to be a grad student studying the relationships between plants and nectar feeding bats, an avid birder adding a few more species to his life list, one of the world's leading expert on ferns, or an artist working on her watercolor techniques. That fit looking guy down at the end of the table that just went back for a third helping of the chicken in passionfruit sauce is probably on bike tour.

It can all make for some interesting conversation. I was reminded of this last week when I ended up at the lunch table with a group of volunteers that represented exactly seven different nationalities. We discussed the merits of volunteer adventure travel over large servings of fresh salad, worked our way through the must-see cultural attractions of home towns on four continents over a hardy main course, and had settled down over dessert to a mix of perspectives on global health, water security, and the odd habits of flower mites that hitchhike on the bills of hummingbirds. So, next time you are at the station, take the time to talk with someone outside of your group (assuming, of course, that the person looks like they'd welcome conversation); you might pick up some new travel tips or a little known fact about the sex life of heliconia plants.

The rest of this newsletter contains articles on the strange relationships between ants and other arthropods, the exotic history of the king fern and the changes and challenges to the delicate forest ecosystem of our region. You will also find some stories from the field by researchers at our sister biological stations and updates on some exciting new additions for visitors at the Wilson Botanical Garden. Enjoy!

What's New at Las Cruces?

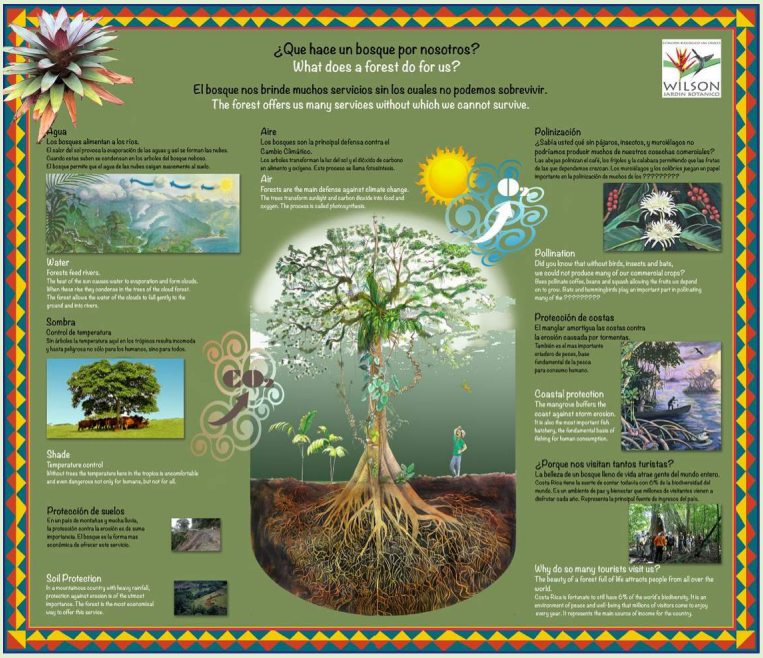
The Art of Science Interpretation

Rebecca Cole / rebecca.cole@tropicalstudies.org

On your next visit to the Wilson Botanical Garden, you will see a new structure on the hillside between the dining hall, the library and the reception building. Sheltered from the rain and sun under a high roof are eight large aluminum panels making up a new Visitor Information Area. The panels are the work of artist Deirdre Hyde who's extraordinary career of science and nature interpretation has enlivened museums, national parks, art galleries and even places such as the Vatican over the past 30 years.

Over several months, Deirdre worked with staff at Las Cruces to create a rich exhibit that takes the viewer through the history of our region, the adventures of early settlers, and the science that explains how our actions are changing this part of the world. Original art blends with traditional indigenous patterns and themes to create a sense of continuity and carry a strong message of conservation and stewardship of our tropical environment.

On your next visit, take a few minutes to check out this gorgeous new addition to the garden!



What does a forest do for us?

Vertical Gardens

Thanks to the talent of volunteer horticulturist, Rodrigo De Sousa, Las Cruces has it first vertical gardens. At the entrance of the station, native bromeliads form a living backdrop to a new welcome sign. The novel design is providing a new favorite photo spot for our visitors. Down in the Zen Water Garden, a Japanese lantern is perched atop a second vertical garden of bright green ferns.

Exploring in the new Sala de Educación Ambiental

The Natural History Room

Thanks to the amazing generosity and talent of our local community, the room adjacent to reception has been converted into a natural history exhibit and learning center. From hands-on activities that show how erosion works to food webs to exhibits that contains sounds and smells, the small space is full of surprises. Designed by talented local artists, illustrations of insects fly and crawl across the wall, a family of agoutis scurry along the lower levels and a ceiba tree presides over a potting and seed exchange area. The Natural History Room is great new addition and a nice place to browse through on a rainy afternoon.

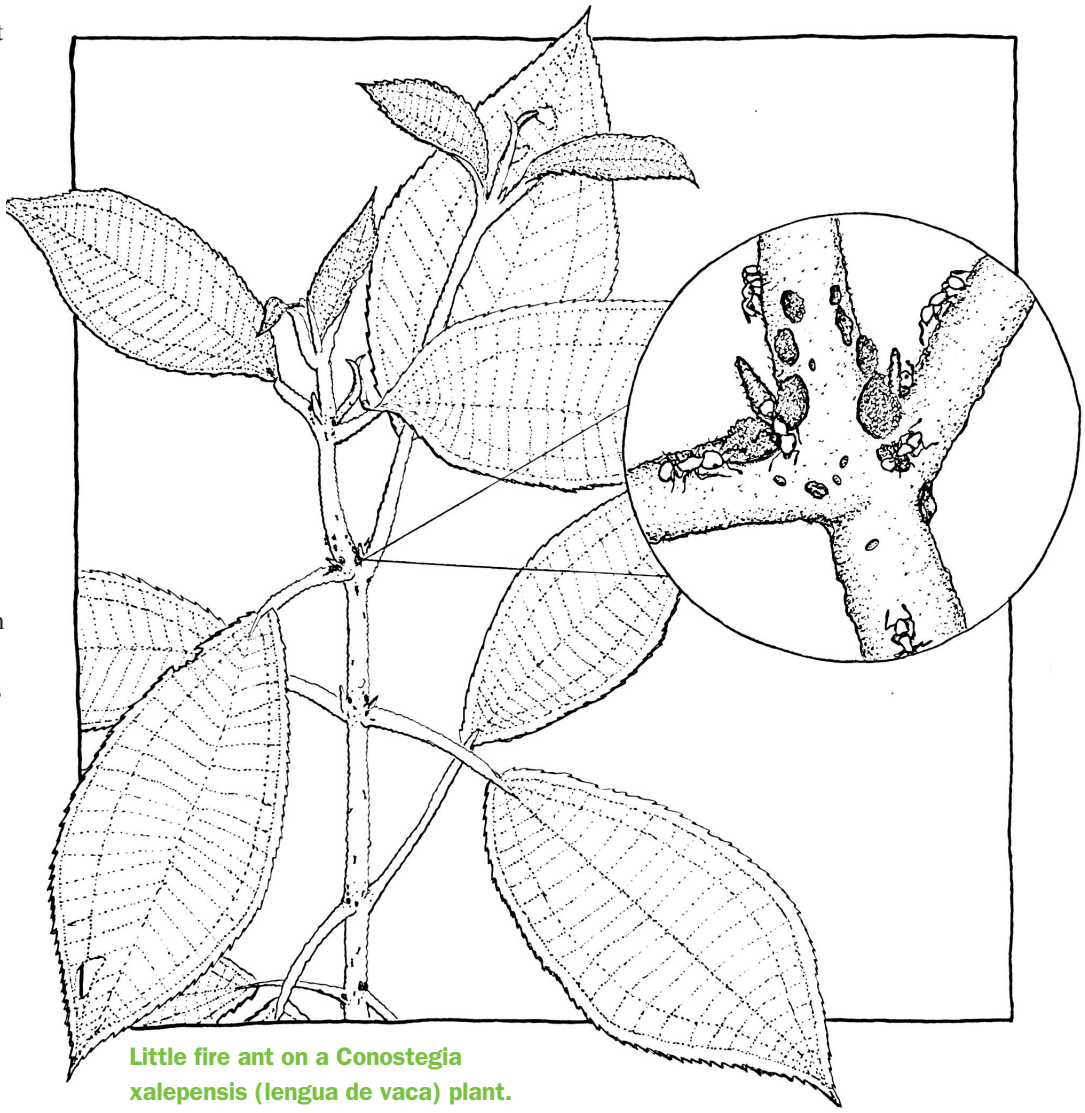
New signage against a backdrop of bromeliads

Research at Las Cruces

When good ants go bad: novel mutualisms in restored tropical forests

Andy J. Kulikowski, University of California- Santa Cruz / akulikow@ucsc.edu

As an insect ecologist that works in restored tropical forests, I've had the pleasure of sampling multiple flavors of insect bites, stings, and burns. Some are like hot pokers that hit you fast and hard. Others have a lingering, spicy quality that I must admit, can be somewhat pleasant. But by far the most interesting and surprising sting I've encountered is that of my study organism, the little fire ant, *Wasmannia auropunctata*. Barely noticeable at first, the venom slowly spreads from the sting site initiating 20 minutes of fever-like tingles up the spine that culminate in what I can only describe as searing electricity. What's most surprising is that it all comes from an ant barely larger than a grain of sugar.



Little fire ant on a Conostegia xalepensis (lengua de vaca) plant.

Given a chemical prowess that outmatches many of its larger cousins, it's no wonder that *W. auropunctata* can also pack quite the ecological punch. The minute ant is native to Costa Rica and other parts of the New World tropics where – in undisturbed forests – it takes its place as an unassuming member of the understory community. But within a human-disturbed or agricultural setting its population can explode with drastic consequences for insect diversity and ecosystem function. While the mechanisms are not entirely known, it's speculated that the little fire ant's hyper-generalist foraging behavior, potent sting, and high tolerance to different environmental conditions allow it to outcompete other understory ants in human-modified habitats. This has led to multiple invasions around the world where *W. auropunctata* has decreased insect diversity, threatened vertebrate populations, and posed a danger to workers in agricultural landscapes. In disturbed areas within its native range, it can completely dominate the ant community. This is especially concerning for researchers like myself that study forest restoration because diverse tropical ant assemblages provide multiple ecosystem functions such as seed dispersal and predation that may be affected by *W. auropunctata* dominance.

Population explosions of *W. auropunctata* are concerning enough but the ants often acquire accomplices in their quest for dominance. Honey-dew secreting insects in the order Hemiptera such as aphids provide a nutrient rich resource for the ants. In exchange, hemipterans and the plants they live on receive protection from the ants. Many of us are familiar with similar obligate mutualisms such as those between *Azteca* ants, *Cecropia* trees, and scale insects. These types of mutualisms are tightly coevolved with all members

Andy Kulikowski and Ana Rubio classifying ants in the lab at Las Cruces. Courtesy Benj Drummond.

requiring the mutualism for survival. In contrast, *W. auropunctata* forms *facultative* mutualisms with plants and hemipterans without a strong evolutionary component. Thus, when habitats become modified, there's a risk of novel relationships forming between little fire ants and previously unassociated hemipterans.

This appears to have happened in our restored forests where the little fire ant tends the scale insect *Alecanochiton marquesi*. This is startling for two reasons. First, not only is this the first record of *A. marquesi* in Costa Rica but this is the first time it has been observed feeding on plants in the family Melastomataceae which are well represented in Coto Brus. Second, it has been reported as a coffee pest elsewhere in the tropics and could potentially pose a threat Coto Brus' coffee industry.

To further add to the conundrum, *A. marquesi* and their ant protectors predominately infest the early-successional tree *Conostegia xalepensis* (*lengua de vaca* in Spanish) and may be decreasing herbivory on young trees. This could be bad news from a restoration context because the goal of ecological restoration is to accelerate forests towards an old-growth state and the overabundance of early-successional trees like *C. xalapensis* could slow recovery or even arrest succession altogether.

Amidst this tangled web of interactions, I have been investigating how the mutualism works and what it might portend for tropical forest recovery. I first collected and transferred *A. marquesi* scale insects onto planted *C. xalapensis* seedlings in 14-year-old restored forests. While the restoration strategy used in each forest was the same, each site has a different level of surrounding forest cover ranging from 10-89%. This design allows me to study whether the mutualism is affected primarily by large scale deforestation on the landscape or smaller scale processes within the restored forests themselves. I then prevented ants from colonizing and tending the scales on half of the plants using a strong adhesive on the stems. For three months, scale insects were allowed to propagate uninhibited before I collected, counted, and preserved them.

After the initial data analyses, I observed both some expected and surprising results. First, nearly all ant-allowed plants were colonized exclusively by *W. auropunctata* suggesting that – at least for this resource – the little fire ant is dominant in these plots. Second, as predicted, I observed a significant increase in scale abundance on plants colonized by *W. auropunctata* compared to ant-excluded plants suggesting that these ants are indeed protecting the scales. The final result thus far is perhaps the most compelling. When I added the level of surrounding tree cover to the analysis I found that scales on ant-excluded plants have significantly higher mortality due to fungal attack but only in sites with high adjacent forest cover. Put another way, it appears that proximity to forests provides an important source of fungal pathogens that help control scale outbreaks, but only when ants are absent. Thus, it appears that *W. auropunctata* can counteract natural biological control of scales. In the next phase of the research, I will examine if the presence of ants affects herbivory on *C. xalapensis* seedlings and whether there are any measurable differences in plant health as a result. This will help illuminate how novel mutualisms like this one can affect plant communities in restored and recovering ecosystems.

While ongoing, this research brings to light an important point when thinking about ecological change. Understanding the effects of species loss is indeed vital to conservation efforts but investigating how habitat degradation promotes novel and potentially detrimental interactions between remaining species is also integral to any conservation agenda. The work also highlights the essential ecosystem services like biological pest control that intact forests provide and underscores the importance of preserving the few forests that remain standing.

Measuring a tree's diameter on an extension ladder in the forest! Photo credit Federico Oviedo-Brenes

What happens to a forest fragment long after it is isolated?

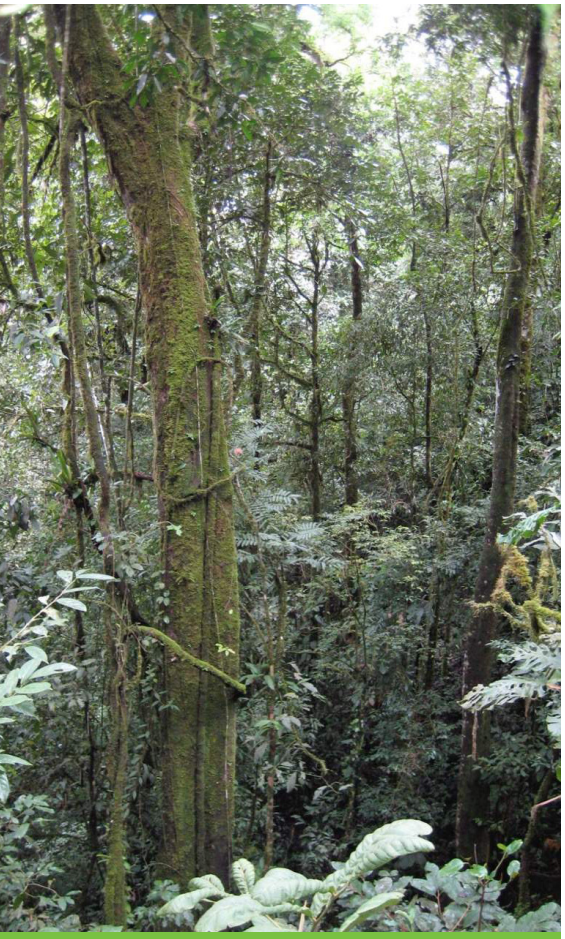
Rakan A. Zahawi, University of Hawaii/ zahawi@hawaii.edu

As Fede and I hauled the clattering six-foot extension ladder through the dense underbrush of the Las Cruces forest, and up a slick steep slope for the umpteenth time, I tried to remind myself that something would come of this massive effort to try and quantify how an interior forest plant community responds to isolation. It is well known that habitat loss and fragmentation are among the biggest threats to tropical biodiversity and associated ecosystem services the world over, and in that regard southern Costa Rica provides a great example to work with as the area around Las Cruces harbors only around 25% of its original habitat. Most of this forest loss and fragmentation occurred between 1960-1980 when almost half of all forest in the region was eliminated (for more on that see my earlier Amigos installment #86, November 2016). Las Cruces was one of the few remnant patches left and starting in 2007 I, along with a number of fellow researchers, set about the arduous and slow task of establishing a permanent plot in the center of the forest reserve to evaluate how this remnant patch of habitat was "behaving" in light of its physical isolation that began in the late 1970s. Key participants included the former Las Cruces taxonomist Federico Oviedo-Brenes, Chris Peterson from the University of Georgia, and a host of students and volunteers that helped out at one time or another.

We began by gridding a 2.25-hectare area (150 x 150 m) at 10 m intervals using a total station – an instrument that is designed for surveying, typically in more open areas than a dense tropical forest understory environment but you can make it work even though lenses tended to fog up frequently! This permanent plot was established in the center of the old-growth forest (>400 m to any forest edge) and we did this to avoid some of the well documented deleterious effects that a forest edge can have such as higher temperatures, drier conditions, more wind shear and consequently shorter canopies and younger trees, and a suite of other characteristics that can penetrate up to 100 m depending on the variable. By avoiding that initial buffer area, what we really wanted to assess is how well the *interior* of this particular forest patch was holding up – and based on other studies of forest fragments we presumed it would be ok.

Once we had our plot laid out, all plants >5 cm diameter were censused, mapped, and identified to species in two separate surveys that were taken ~5–6 years apart. This was no simple feat as each census covered upwards of 3,000 stems (!). Also, some trees at Las Cruces are huge and present challenges just to get a measuring tape around them. For instance, many trees have big buttresses so getting an accurate measure of their diameter (to assess Carbon stored among other parameters) we had to measure above where the buttresses ended. That is where the extension ladder comes in, and good thing I don't have a fear of heights as there were some pretty precarious locations where we placed it! At times I was ~6 m up on a ladder with an incredible drop off on the other side

A tree tag with a unique ID number given to each individual. Photo credit Rakan Zahawi



An unparalleled view of the Las Cruces forest from the top of a ladder. Photo credit Rakan Zahawi

of the tree that nonetheless gave you an unparalleled and breathtaking view of the surrounding forest. It was also a lot of fun collecting this data and there are countless stories to tell about our many excursions to census this little forested patch of the world. We went out so many times that I can picture certain locations in my mind even now – not surprising as Fede and I collectively put in hundreds of hours of field time into this effort!

So what did we find? Well the results are mixed. Although the reserve maintains high species richness (>200 species were censused each time), many were rare and represented by only one individual (that is pretty astounding when you think about it). We also documented a strong shift in species composition between surveys. More worrisome was a two-fold increase in the number of soft-wooded pioneer individuals – an indication of increased disturbance effects *even though we were in the center of the Las Cruces forest*! Some species, such as the dominant late-successional understory tree species in the 1st survey, *Chrysochlamys glauca* (Clusiaceae), and most species in the Lauraceae or avocado family, declined dramatically. Stem turnover was also exceptionally high: 22.9% of stems in the first survey were lost by the time of the second survey, and 27.8% of stems in the second survey represented new recruits. That is a lot of change in a few years and not surprisingly mean tree diameter decreased alongside a 10% decrease in aboveground biomass or Carbon storage.

What does this all mean? Well in short there is a lot more change happening than what you would expect. Such alteration has been documented elsewhere but only in much smaller fragments or within ~100 m of an edge boundary. Something else is happening here and it's taken ~40 years of isolation to really become notable and could lead to the loss of some species – especially those that are particularly rare. It could be driven by a progressive invasion of disturbance-adapted species into the fragment's core over time – so a skipping stone type of effect that eventually fills in the entire fragment. Alternately, the loss of once-dominant late successional species could be a contributing factor by creating gaps for other individuals to colonize. Other factors could be the loss of dispersers or climate change driving big shifts in community composition. It's hard to say without more invasive experimental studies but the pattern found is of concern given that such fragments represent a substantial portion of today's remaining tropical habitat. What is really needed are further studies in similar-sized fragments that have been isolated for equivalent periods of time to see if this pattern holds true elsewhere. As far as Las Cruces is concerned, what would be best is to continue to expand the reserve area and ultimately try and connect it to other protected areas so they can collectively buffer against the effects of increased disturbance that we documented here.

The details of this study were published in the journal PLOS ONE and the article can be accessed via the following link: https://doi.org/10.1371/journal.pone.0183133.

Stories from the Field

Palo Verde: Natural History Ramblings

Jim Hamrick, Former chair of the board of directors, OTS

During supper one night at OTS' Palo Verde Field Station, Rebecca Cole asked me whether I would be interested in writing about some of the natural history observations I have made during my research trips to the Palo Verde station over the last 25 years (1993-2018). Before we get to the natural history, perhaps a brief history of how and why I conduct research in Costa Rica's tropical dry forests would provide some context.

My interest in conducting research in the Neotropics began during the fall of 1982 after a seminar given to the University of Kansas Division of Biological Sciences by Steve Hubbell. While walking to lunch after Steve's seminar, Steve asked me whether I thought one could use genetic markers (allozymes in those days) to study genetic diversity in tropical tree populations. My answer was something like, "I can't think of why not since I doubt that tropical trees would present any more technical problems than temperate trees such as pines and oaks." Steve proceeded to tell me about the 50 hectare plot that he and Robin Foster had recently established on Barro Colorado Island (BCI) in Panama.

To make a long story short, Lyn Loveless (a soon to finish graduate student at KU) and I wrote a grant proposal to the U.S. National Science Foundation (NSF) over the Christmas 1982 break. It was funded and after graduating Lyn headed to BCI during spring 1983. Fast-forward to 1987. By then, I had moved from Kansas to the University of Georgia. In the spring of 1987, I attended a meeting in Costa Rica of the representatives of the member institutions of OTS. Over the next four or five years, I attended OTS meetings at the Las Cruces and Palo Verde OTS stations, as well as those in San Jose. Finally, in 1992 John Nason (my post-doc at the time) and I wrote a NSF proposal titled "Estimating gene flow into tropical forest fragments." We proposed to study forest fragments in three sites; the islands in Lake Gatun, Panama and terrestrial fragments in the vicinity of Las Cruces and Palo Verde National Park. John focused his efforts in Panama while my student, Preston Aldrich, worked at Las Cruces and another of my students, Victoria Apsit, and I focused on Palo Verde. Soon after that I shifted the majority of my personal tropical research to the tropical dry forests of Guanacaste, C.R., where I fell in love with the Guanacaste tree, *Enterolobium cyclocarpum*. Other dry forest trees that we studied were *Hymenaea courbaril* (guapinol) and *Spondias purpurea* (jocote).

Now for a little Palo Verde natural history. Botanists and foresters (especially) are fascinated by large trees. Most states in the U.S.A. have identified "champion" individuals for most of their tree species. Palo Verde National Park is the home of the largest specimen of Pochote (*Pochota quinata* – was *Bombacopsis quinata*) that I have seen. The tree is located on Catalina Road across the road from the Catalina ranger station, approximately 8.1 kilometers from the junction of Catalina Road with the main park road to the OTS Palo Verde field station. The tree is approximately 60 meters from the road behind a heavy cover of small trees. The tree's trunk is hard to see from the road but the crown is relatively easy to locate. It was difficult to measure the tree's diameter but our best estimate is approximately three meters. It is certainly worth working your way through the grove of small trees to get a good look at this tree. Another quite large Pochote can be found on the trail that parallels the road between the OTS station and the mango-shaded picnic area close to the Palo Verde National Park Headquarters. This tree, however, has only half the girth of the Catalina tree.

Pochote's large white flowers are bat-pollinated and its seeds are wind-dispersed. It flowers during the dry season (February to April) and its fruits mature from March to August. The wood of Pochote is highly valuable and, as a result, most of the larger Pochote trees have been cut down throughout its range.

PALO VERDE Research Station, located in the 20,000 hectare Palo Verde National Park, holds one of the largest and most important Central American wetlands and harbors one of the most intact patches of tropical lowland dry forest remaining in Central America.

PALO VERDE wetlands maintain a tidal relationship with the Tempisque River and delta, and are home to many species of native and migratory aquatic birds, including the magnificent jabiru.

OTS, in collaboration with the Costa Rican Ministry of the Environment, have worked together to restore the wetland threatened by the encroachment of invasive plants, resulting in the return of more than 60 species of birds.

Flora and Fauna

A king fern originally planted at Las Cruces by Robert Wilson in 1965.

Captain Bligh's Fern

Robbin C. Moran, The New York Botanical Garden / rmoran@nybg.org

In 1965 Robert Wilson planted a row of king ferns (*Angiopteris evecta;* Marattiaceae) along the Río Java trail about 100 meters before it enters the forest. Over the years, these ferns have become huge, with massive trunks about one meter tall and gracefully arching leaves four to six meters long (Fig. 1). Native to the islands of the western Pacific, the king fern has a remarkable story about how it arrived in the New World and came to be cultivated at Las Cruces. Also remarkable—and cause for concern—is the fern's "behavior" at Las Cruces since its original planting by Wilson.

But before explaining the king fern origin in the New World and its behavior, a few notes about how to identify it. Two easily observed characters reveal it belongs to the Marattiaceae, the oldest family of extant ferns, one that boasts a fossil record extending back to the Carboniferous over 340 million years ago. The first character is two fleshy ear-like structures, called stipules, that flank the base of each leaf stalk where it joins the trunk. The second character is that the pinna (leaflet) stalks are conspicuously swollen where they join the midrib of the leaf (Fig. 2). No other fern family has these two characteristics; they absolutely diagnostic of the Marattaiceae. *Angiopteris*, the genus of the king fern, differs from other genera in the family by sori consisting of two rows of spores cases that are free, not fused as elsewhere in the family.

The king fern was brought to the New World by the famous British naval officer, Captain William Bligh (1754–1817). (If you doubt Bligh is famous, consider this: Five movies have been made about him, the first in 1916—a silent film—and the most recent in 1984, in which he was portrayed by Anthony Hopkins). In 1788, Bligh set sail for Tahiti in command of the HMS *Bounty.* His mission was not to acquire the king fern but to obtain saplings of the breadfruit (*Artocapus altilis;* Moraceae) and transport them to the West Indies. There the breadfruit would be cultivated for its large and edible fruits that would be used as food for slaves on the sugar plantations.

This voyage of Bligh's ended in disaster. Shortly after departing Tahiti, the crew mutinied in a famous incident popularly known as the "Mutiny on the

A tell-tale sign of the Marattiaceae: a swelling at the base of the pinna midrib where it joins the rachis, or midrib of the leaf. Note also the sori (light lines) near the margin of the secondary leaflets.

Bounty". Bligh and 18 of his loyal men were set adrift in a small launch with few supplies, and against all odds, they survived an open-ocean voyage of about 6,701 km (4,164 mi), finally reaching the island of Timor. From there Bligh made his way back England where, undaunted, he set sail a second time for Tahiti (1791). This time he was to acquire not only breadfruit, but also other plants of potential economic use. Among the other plants he procured was the king fern, whose large starchy stems and leaf stalks were eaten by the Tahitians. (A breadfruit tree can be seen at Las Cruces between the workshop and greenhouses. At the La Selva Biological Station, a breadfruit tree can be seen west of the Stone Bridge, in front of the first researcher cabin).

Bligh's second voyage was successful. In 1792 he off-loaded breadfruit and other plants in St. Helena in the mid-Atlantic and then sailed to St. Vincent and Jamaica. In Jamaica, the plants were brought to the Bath Botanic Gardens. The king fern languished there for decades in cultivation, along with breadfruit, until the 1860s when it was transferred to more favorable growing conditions in Castleton Gardens, also in Jamaica.

As an aside, it turned out that most slaves on the West Indian sugar plantations refused to eat breadfruit, but the plant was eventually adopted in Jamaican cuisine and is still popular today. It is usually served as an accompaniment to ackee and saltfish, the national dish of Jamaica. Speaking of ackee, that plant is also plant associated with Bligh. Native to West Africa, ackee was shown to Bligh in Jamaica. He then then took the plant to Europe for study by botanists, who named it in his honor: *Blighia sapida* (Sapotaceae).

But back to the king fern. In the 1950s, Charles Lankester acquired cuttings of the fern from Castleton Gardens in Jamaica and planted them on his property in the town of Cartago—what is today known as the Lankester Botanical Garden. Lankester then gave cuttings to Robert Wilson for cultivation at Las Cruces. (The cuttings that Lankester provided Wilson were probably from the stipules of the king fern. These cuttings, when placed in moist sand, proliferate new plantlets along their margins. The plantlets can be placed in the soil once they have reached a suitable size. Members of the Marattiaceae are typically propagated this way. John Mickel, my predecessor and colleague at the New York Botanical, once wrote an article about how to do this, titled "*Marattia* propagation stipulated.")

Since its planting at Las Cruces in 1965, the king fern has staged a "mutiny" of its own. It has rebelled from the confines where originally planted by Wilson and spread into the nearby forest. Its dispersal has been by air-born spores; the fern has no other means of reproducing, such as long runners or proliferous buds. Reproduction by spores is evidenced by the many gametophytes (the sexual phase that develops from spores) of king fern found on exposed soil and steep banks, especially along streams. The gametophytes are slightly smaller than a 50 colones coin (about the size of a US quarter) and resemble a thick, green thalloid liverwort. The first leaf that develops after fertilization pushes up through the center of the gametophyte tissue; it does not curve upward around its edge of the gametophyte as in nearly all other ferns. This character makes king fern gametophytes easy to identify (I love showing them to my students on the OTS courses *Tropical Plant Systematics* and *Tropical Ferns and Lycophytes*).

Although no quantitative data are available, the king fern seems to have increased over the decades in the surrounding forest. Some large and presumably old individuals can be found well within the forest where Wilson almost certainly did not plant them, and new baby plantlets appear frequently along trail banks and stream sides. The fern has become similarly naturalized at other botanical gardens in Latin America and in Hawaii. Of course, the problem with such large, non-native, aggressive plants is that they crowd-out and over-shade the native species that managers are trying to protect. What should be done at Las Cruces?

It would be sad to eradicate Wilson's original plants. They have delighted visitors for decades and are part of the history of Las Cruces. But unless something is done, the king fern might extend farther into the forest and eventually invade neighboring properties and beyond. Fortunately for land managers, large mature plants are easy to find in the forest—a quality that would facilitate eradicating them if that is decided by managers to be their fate. The fern is also a slow-grower. This might give decision-makers time to prepare for how to deal with the pressing difficulties of the situation.

Removing birds from the mist net.

Malaria in southern Costa Rica! But not in people, in birds!

Scott T. Walter – REU Coordinator and Faculty /
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The tropics are full of biological and cultural riches, yet they are also home to malevolent parasites that are the lore of deep dark rainforests. One of those parasites, malaria, has affected millions of people in tropical regions around the world. Fortunately, human cases of malaria in southern Costa Rica are rare. But could malaria actually be here in the *birds* that frequent the Las Cruces Biological Station?

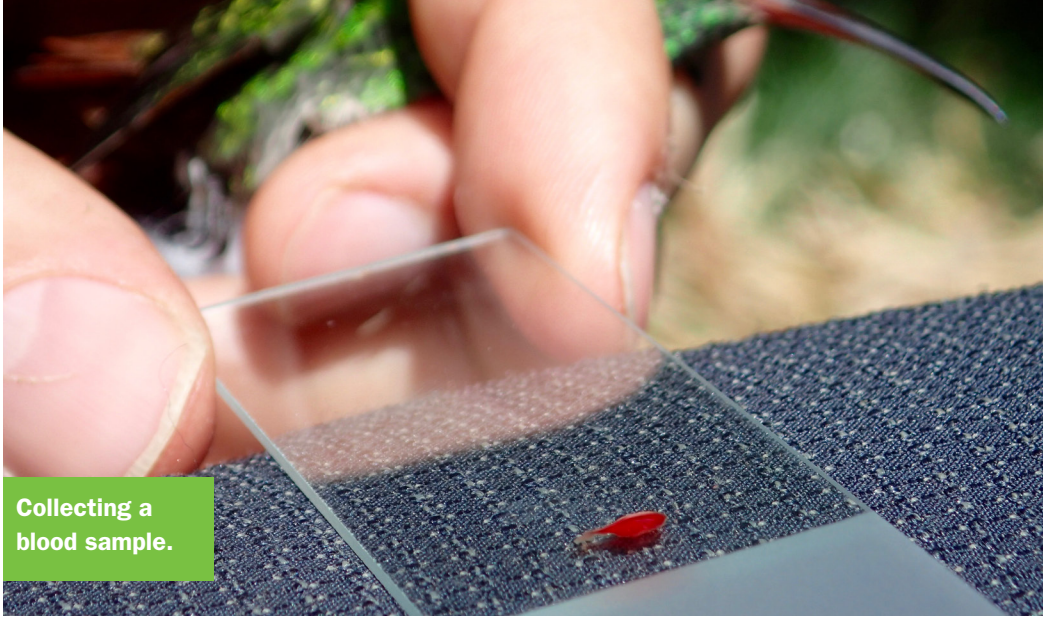
The answer to whether avian malaria exists across the large community of birds in the south of Costa Rica was relatively unknown, at least until this summer when a small team of researchers investigated the question. These biologists were among the 16 undergraduate students that gained hands-on experience in scientific research as part of the OTS Research Experience for Undergraduates (REU) program at Las Cruces. This NSF-sponsored program is unique in that it supports students from traditionally underrepresented groups in the sciences, such as Hispanic Americans, African Americans, Native Americans, and South Pacific Islanders. From this cohort of students eager to gain hands-on field experience, Karina Flores and Jaime Botet Rodríquez led the avian malaria project under the mentorship of Dr. Juan Rivero, a Spaniard who has worked with blood parasites around the world. Both Karina, a first-generation Hispanic attending the University of Oklahoma, and Jaime, a Puerto Rican Latino enrolled in the University of Puerto Rico, had previous experience with parasitology in the laboratory, but neither had designed and implemented a field study of their own.

Although establishing research questions was straight forward for Karina and Jaime – collecting data was not! To sample for avian malaria, each morning the research team set off from the field station at 4:30 AM to hike to one of three study sites in order to evaluate the effect of different habitat types on the possible prevalence of the parasite. They set up mist nets to capture birds and quietly waited for unsuspecting birds to fly into the nearly invisible net. Ironically, while awaiting birds to sample for malaria, the research team endured the usual tropical onslaught of biting mosquitos, the vectors responsible for the transmission of malaria to people and wildlife (although humans are not susceptible to the particular strain of malaria that affects birds). While the undergrads pondered this blood-sucking paradox, woosh, a bird would fall entangled in the net. The students would then delicately remove the bird (Fig. 1), and once the bird was in hand it would receive a

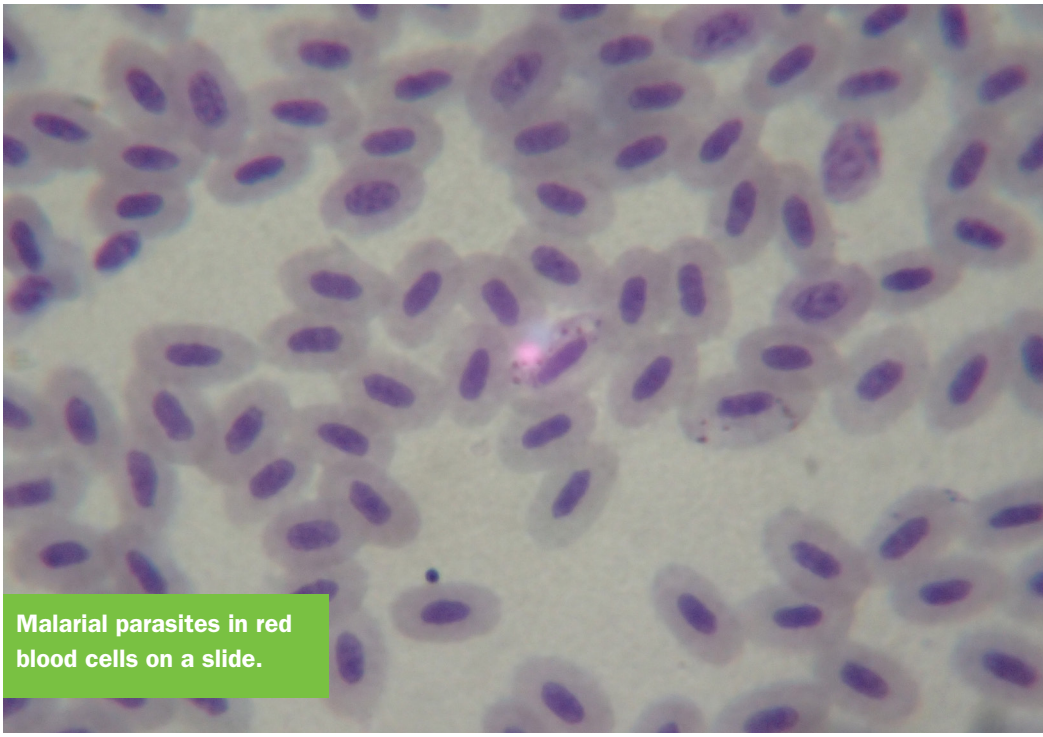
quick prick to its wing vein – not from a biting mosquito like usual, but from a small needle in order to collect a drop of blood.

The final phase in data collection entailed viewing the birds' blood smears on glass slides in the lab beings that it is in the red blood cells where malaria parasites are found (Fig. 2). After six weeks of field work, a total of 94 blood samples were collected from individual birds, which were comprised of 39 bird species. Work that started in the dark hours of the morning to capture birds transitioned in to the dark hours of night while peering through a microscope at tens of thousands of red blood cells. It was like finding a needle in a haystack, but alas, Karina and Jaime spied the first infected cell – avian malaria exists at Las Cruces! The malarial infection is clearly distinguished as a protozoan-like structure pressed up against the cell nucleus (Fig 3). Emotions ranged from excitement in seeing 'text-book information' in real life, recalls Karina, to a sense of awe in the realization that they had developed a proficiency in conducting novel research and discovering new information, says Jaime. Although the results were exciting, they did reveal that a potentially deadly infectious disease was present in birds in southern Costa Rica.

At the end of study, the research team determined that only about 5% of the birds they sampled were infected with malaria and habitat type had no effect on the incidence of the parasite. This prevalence is at the lower end of the 3 to 18% prevalence found across various Neotropical countries. Infected birds at Las Cruces were the White-throated Thrush, Rufous-capped Warbler, White-breasted Wood-Wren, Rufous-tailed Hummingbird, and the Scaly-breasted Hummingbird. The White-throated Thrush was one of the species also found infected through other research in northern Costa Rica; coincidently the International Union for the Conservation of Nature (IUCN) has reported its population size to be decreasing. As such, it will be important to understand what factors make the White-throated Thrush seemingly more susceptible to malaria that could affecting the bird's population viability.



Collecting a blood sample.



Malarial parasites in red blood cells on a slide.

In the sciences, it is common that with answers to original questions, come new questions. This is the time-honored process of building knowledge. Thus, the results are in – there is avian malaria in southern Costa Rica – but what this means for bird populations is the next question. Fortunately, through field training, such as that received by Karina and Jaime through the mentorship of Juan and others, there is a growing body of capable young scientists prepared to answer these conservation questions. Even better, we are training underrepresented minorities to conduct the research, which creates a more diverse cadre of scientists. Following this REU program Karina is planning to pursue a Ph.D. in pathology with an emphasis in parasitology, and Jaime plans to pursue a degree in veterinary medicine (DVM) and a master's degree in wildlife infectious disease. We look forward to having them both back in Costa Rica to solve environmental problems and to serve as role models in training the next generation of young scientists and to pass on some 'Pura Vida'.

Our Donors

The Magic of a Pollinator Garden

Greg Nace, Horticulturist at Wilson Botanical Garden

The pollinator garden today.

Common visitor in the pollinator garden. Courtesy of Randall Jimenez.

It was January of 1983 when I boarded a plane in cold and rainy Philadelphia to travel to Costa Rica for the first time. Together with my two classmates in the Longwood Graduate Program, I was excited to escape winter weather and spend a month at Las Cruces. This is when Robert and Catherine Wilson were still actively tending to their dream of building a tropical botanical garden. I was there for a month and made the very first map of the plant collections.

In 2017, after a lapse of 34 years, I returned to the Garden, this time with coaxing, accompanied by my wife BJ. Are you sure there's going to be internet? Thanks to a grant from the Stanley Smith Horticultural Trust, I was brought on as the Horticulturist to refresh the 55-year-old Garden. We lived in one of the lovely casitas on the property for nine months. Surrounded by tropical rain forest, monkeys and toucans frequented our back yard.

Memories of what the Garden had looked like when I was a student came back slowly. Bromeliad Hill designed by Roberto Burle Marx looked about the same, but the rest of the Garden? It looked so different. I could hardly recall seeing it before. I was unprepared for how 34 years of 147 inches of annual rainfall could alter the tropical landscape. It was unlike anything in temperate zones. The Wilsons started off with a cow pasture, but now the trees, palms, ferns, antheriums, etc., flourished across the enormous collection. With everything covered in moss, the Botanical Garden seemed to blend almost seamlessly to the adjacent primary forest. Boundaries where the Garden ended and the primary forest began were blurred. The jungle was still as dark and wild as it should be, but the Garden now reflected some of this wildness in the exuberance of its plantings.

One of the key projects I worked on in 2017 began as a Hummingbird Garden. Designed by Osamu Shimizu, a renowned master landscape architect from the Washington DC area, it is laid out in concentric circles with a dripping fountain and pool as its centerpiece. When I arrived in March of that year, the beds had been outlined with Mondo grass. However, except for a couple plantings of Stachytarpheta jamaicensis (Blue Weed), little else was planted. Hummingbirds found these flowers, but so did butterflies. So, why don't we broaden the scope of this garden and include plants to attract a range of pollinators? With the help of Rosi and Jesus from the staff, pollinator plants

Bee visiting false heather flowers (Cuphea hyssopifolia). Courtesy Jeisson Figueroa.

began to be collected and propagated. Grass was gradually replaced with an array of plants known to attract pollinators: birds, bees, butterflies and of course, hummingbirds (some of the 50 species found in Costa Rica). When BJ and I left in December last year, the Pollinator Garden still looked like a young garden with nothing much in flower, but the surprise was yet to come.

BJ and I returned to the Garden to volunteer in July this year. Our reaction when we saw the Pollinator Garden was sheer amazement. Amazed how much the plantings had grown in the six months since we were last here. Plants were flowering, and the pollinators were there to tend to them. How quickly plants grow here! A garden that in North Carolina where we are from would have taken years to fill-in. But here, it only took six months! It truly gives hope that tropical forest regeneration can succeed. It just takes the magic and science of tending the earth, and letting the sunlight and rain do their work.

Can paradise be recreated? Doubtful, but working for botanical gardens my whole career has taught me that planting keystone species of fruits and flowers helps make things right in the world. If you are interested in helping with the magic, we would welcome your visit as a guest or volunteer. The food and facilities are top notch. Also, the Wilson Botanical Garden and Las Cruces Research Station need your financial contribution to continue to make a difference. A difference in both the art of horticulture and the science of regeneration. Naming the Pollinator Garden in honor of, or in memory of, a loved one is also a tax-deductible option.

As always, a big THANK YOU to you all!

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