NECTANDRA INSTITUTE

Jan 2018, Vol. 18 No. 1

Playing Spider Woman

I was flat on my back, looking up. There it was, bearing straight down toward me at a steady 0.5m/sec, then softly came to a dead stop inches from my nose. It was a tiny orange red spider, twice the size of the comma on my keyboard. From the 3.5 m (~12 ft) ceiling, it detached with a half summersault, floated head down attached by its extruded silk and just stopped. It felt my breath! Its motion was effortless, seemingly stunningly simple. I blew on it softly. Silk and spider swung in a soft arc to the left. When it came by my nose again, I sent it to the right. The little red rider stayed put, and calmly enjoyed our game of swing for several more minutes. *Darn, I wish I could do that!* Suppose I play spider, could I do what I just saw? What would be involved? What are the challenges?

First, how do I attach to the ceiling? I would need reversibly-adherent shoes, capable of holding my 56 kg body until release. Not a challenge. Thanks to gecko-inspired reversibly-sticky fabrics, I can have gravity-defying shoe soles made of either carbon nanotubes textile (300 kg limit) or a cheaper version (100 kg limit), both reusable up to 100 times.

Next, I need rope. I am 785 times the spider size based on body length. To bungee jump the spider's equivalent of 3.5m, I would need 3.5m x 785 = 2750 m (~9000 ft) of rope. My research into ropes made my head spin. Proper climbing rope selection involves the evaluation of a large number of factors — strength, working loads, climatic conditions, material breaking limits (spliced, non-spliced), applications (climbing *vs*. safety), climatic conditions, physical locations, just to name a few. Modern ropes come in different load bearing strength, firmness, construction, abrasion and stretch properties. There are at least 8 types of fibers with different physical characteristics (melting point, critical temperature, density, and deformation under continuous load, etc). They come woven in varying diameters and in dizzying types of braided construction, *e.g.*, 3-strand twisted, 8-strand plaited that uses 3-strand twisted sub-ropes, 12 or 16 -strand plaited, shielded, etc. Every situation and application requires a specific rope. It's not difficult to see that jumping off a 20 m cliff differs from a 2000 m drop, or if the weather is wet or sweltering hot. My survival depends on knowing the properties of all the component materials and being able to calculate their combined limits ahead of time.

Multiple other factors also play into my launch from the ceiling. The spider carries the making of its silk in its abdomen. Even if I were to carry (not synthesize a rope *de novo)* a premade rope on my back, its weight alone would crush me. 2750 m of rope of suitable diameter and strength weighs approximately 1650 kg! Let's suppose for simplicity sake, my rope is already fixed to the ceiling and all I have to do is let go. Were I sky diving, it would take me 25 sec to free fall 2750 m — average of 110 m/sec. That's more than 200 times faster than my spider, confirming its ability to control the dive. Yes, I can use rappelling hardware to slow down my roped descent, but what about the heat generated by the friction of rope through the braking hardware. Rock climbers complain of skin burns when rappelling just 60 m and of ropes melting at great speed. Imagine the problems of a 2750 m descent. Then, there is the unsolvable problem (for humans but not spiders) of controlling the spinning and swinging when hanging in mid air. Finally, there is the crushing force of a moving weight when it comes to a sudden stop. The rope needs to be able to stretch sufficiently to absorb the peak energy, else the rope would fail and I would go splat. The spider, on the other hand, floated down with no observable spin and stopped with the grace of a ballerina.

In other words, my playing spider woman is still a fantasy. My mind game served to underscore the wondrous bioengineering behind the silk spinning and the astounding properties of spider silk. That a freckle-size spider is able to accomplish physical feats so beyond our current human technology is magic. What is spider silk anyway?

All spiders make proteinaceous silks, but all silks are not equal. Unlike insects, each making a single type of silk, spiders produce multiple types, each with disparate properties and functions. For example, there are the dragline silks (outer rim and radial spokes of webs) that are strong and smooth, but not sticky to the spider legs. There are silks for temporary scaffolding and for protection of egg sacs. There are sensory silks that are finely tuned for vibrations and those that are impregnated with pheromones to attract the opposite sex. There are silks to wrap freshly captured prey and those for visual defense/camouflage (stabilimenta). There are the sticky beads that are overlaid on the inner web structures to capture prey, and even specialized silks to bond attachment points. Amazingly, a single spider may produce up to 7-8 different types of silk — all extruded through sets of spigots at the tail end of the abdomen. The silk precursors are stored in distinct glands in the abdomen. On demand, the liquid precursors are chemically modified, solidified into fibers, then extruded through specific glands, then funneled through spinnerets that twist them into structurally complex fibrous forms before emerging from multichannel spigots as formed

silks. Structurally, the final silk strands are combinations of spiral (stretchy), zipper (intertwined spirals) and Lego-like (multi-strands locked together for strength) fiber forms. A single strand consists of central fiber bundles, sheathed with exterior layers of reinforcing fibers, very reminiscent of the modern synthetic climbing ropes. Imagine having an entire, self-contained rope manufacturing plant in the tummy of a pinhead size spider!

Given the dream properties of spider silks — lighter, stronger, stretchier, more varied than any man made fibers — it is not surprising to see the intense interest in spider silk research. Spiders trapped in 300 million years old amber already had silk glands. Unknown events followed, leading to the explosion of spider diversity 200 million years later. Today, we know of at least 48,000 species. Genetic sequencing shows that their genome sizes surpass that of humans, with multiple genes for each silk. The silk genes, in turn, contain repetitive and modular motifs that influence the chemical properties and physical complexity of the final structures. Silk biology remains an enigma, but the promises of spider silks have driven countless attempts to harvest or synthesize silk, and dreams of using bioengineering to commercialize this wonder fiber.

Fig. 1 Golden Silk orb weaver *Nephila clavipes (left)* and egg casing (right).

Unlike the docile silk worms, spiders cannibalize when farmed and housed together. The potential for large scale spider silk production came with the cloning (1990) of the Golden Orb weaver (Fig.1) silk gene, allowing researchers to insert the gene(s) into bacteria, yeasts, alfalfa, silkworms and goat (silk protein in drinkable milk!) in the hope of having the host species manufacture copious mimic silk proteins. After much hype, the only consumer goods in the pipelines made from the longer and strongest of synthetic silk products are prototypes — of running shoes (from yeast), men's parka (yeast), designer dress (bacteria) (Fig. 2), and military protective gear (silkworms). To date, scaling up is still a challenge, as is the quality of the synthetic versions. In the meantime, shorter and weaker versions have found many uses in the medical field, including implants, medical pumps, artificial organs and bandages.

Aside from the enviable mechanical properties of the natural spider silks, textiles and clothing designers have been salivating over the beauty of the Golden Orb weaver

Fig.2 Left. Prototype gown from Qmonos (*kumonosu*, Japanese for spider web) fiber by Japanese firm Spiber.

Fig. 3 Right. Cape woven from natural silk of the Magalasy Golden Orb spider, created by artists Nicolas Godley and Simon Peers, displayed at the Victoria & Albert Museum in 2012.

silk since the 1700's. The brocade shawl (Fig 3) exhibited in 2012 at the Victoria and Albert Museum Studio required 70 Malagasies 4 years of labor to collect silk from 1.2 million (80m of silk each) of captured spiders to produce. One meter of synthetic golden Orb weaver silk costs € 29 and one gram for €129 from a Parisian art firm. This spider textile is as impractical as it is beautiful. After all the hype, it is a crushing disappointment to discover that this particular silk shrinks in water and cannot be washed!

We humans are on our way to mass produce one type of silk protein from one spider. The Golden Orb weaver has 27 more silk proteins waiting to be studied. After that there are silks from > 48000 spider species to go.

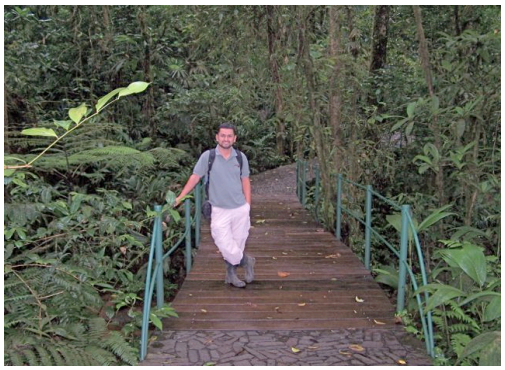
— Evelyne T. Lennette —

Thoughts on my Conservation Experience in Costa Rica

This is Luis' farewell article as a Nectandra Institute staff member. He now returns to his native California after twelve years in Costa Rica. Luis is forever grateful to his Nectandra family for making it a memorable stay.

When I started at Nectandra Institute (NI) nearly eleven years ago, I had no prior experience in the world of conservation. Naively, I harbored visions of fencing off vast swaths of land and allowing the forest regeneration to create more habitat for emblematic wildlife species, such as jaguars, tapirs, and colorful tree frogs. What's more, I assumed it would be as simple as letting people know that the forest was unquestionably important, and conservation would easily follow. Things, of course, did not proceed so straightforwardly.

It seems obvious now, but one of the first curveballs thrown at my original conservation concept was that, even in an ecologically friendly Costa Rica, people have different and complex motivations for wanting (or not) to protect nature. Conservation is not always driven by people's simple desire to protect an endangered species or



The author at the Nectandra Cloud Forest Preserve several years ago, near the beginning of his conservation experience in Costa Rica

a rare ecosystem, such as a cloud forest. Many have self-serving reasons. For example, eco-tourism is a major contributor to Costa Rica's economy. Many depend on the country's national parks, private preserves, and other protected areas for their livelihood. It would not surprise me in the slightest if the number of nature guides per capita in this central American country of nearly five million people were amongst the world's highest. Many have benefited from the pioneering and innovative payment for ecosystem services (PES) scheme (see following article by Manrique Esquivel), which led many landowners to protect their private forest in exchange for monetary compensation, a highly effective motivator in many cases. People can also shift position on conservation depending on the circumstances. This was evident a few years ago, when NI worked with several of our partner communities to commission a hydro geological study. It would allow for wise and prudent site selection on the basis of hydrological importance. A few community leaders opposed. They were concerned that the findings might lead to land-use restrictions that would directly affect them as local landowners. However, on prior occasions these same individuals were vocal supporters of land conservation projects that did not affect them directly. It looks like NIMBY-ism can be an international attitude.

Then there are NI's most important conservation partners: rural community water management associations, or "ASADAS", their Costa Rican Spanish acronym. ASADAS provide potable water service to many of the country's rural communities. There are roughly 1500 of these groups serving 25% of the national population. Each is run by a volunteer board, which is overseen by the ASADAS' members (i.e. residential water users) via general assembly. Although not conservation organizations per se, ASADAS are interested in forest ecosystems for their role as sponges, soaking up rain and other forms of precipitation, facilitating groundwater recharge, which emerges as freshwater springs tapped into by ASADAS. These springs and the groundwater recharge zones higher up on the watersheds rely on healthy forest cover. Knowing this, ASADAS oftentimes work as *de facto* conservationists, motivated by one of the most important ecosystem services nature provides us: clean drinking water.

Another unexpected twist to my conservation work for more than a decade, was the relatively small size of some of our conservation projects with ASADAS and other community partners. Property sizes range from ≤2 to over 250 acres. Nearly 1000 acres of land have been protected thanks to the Eco-Loan Fund and other Nectandra initiatives. The consensus among ecologists and conservation biologists is, to have a real impact, conservation must be done at a large scale: the bigger the better. I have no doubt this is true from the standpoint of protecting biodiversity and securing biological connectivity. However, the value of smaller scale projects in creating societal awareness and conservation support should not be overlooked. For example, I had a recent conversation with a local dairy farmer who is also the president of the ASADA that received the very first eco-loan made by NI. Thanks to his leadership, his ASADA members used the eco-loan in 2007 to buy and protect 27 acres of land where their freshwater spring is located. This property was a cattle ranch surrounded by thousands of acres of farms with low biodiversity and without large tracts of forest. He expressed his belief that this small restoration project has helped shape the conservation ethic of several of the community's youths. They grew up going to the property to plant trees, document the growth of the emerging forest, and learn about the important relationship between healthy forests and properly protected water resources. These youths include his three young adult sons, who were just kids when the community's ASADA purchased the land. His sons, all college students or graduates, have chosen career paths that will likely differ from their father's dairy farming business. Inspired by their experience with the ASADA's forest restoration, the family is planning on turning their cattle grazing land into a small nature preserve. Furthermore, there are two neighboring property owners who also have a conservation mindset. One of them recently sought advice and technical assistance from NI to restore his own property. The awareness and support for conservation shown by these three neighboring private land owners are the direct and continuing ripple effects of Nectandra's conservation work.

So conservation is motivated by different factors, socioeconomic and otherwise, and not always a romantic crusade to save a particular endangered species. It is rarely one-dimensional, but nuanced and multi-faceted. In my eleven years with NI, I have also learned more about myself and my motivations for protecting nature. I came to realize that we live on a finite planet with finite resources. It is difficult to ignore that reality, those very real limits to unchecked growth. I may brush it aside, but I can no longer shut my eyes to it completely. This awareness is ever-present within me; fighting to factor into

the choices I make, choices that have an impact on the planet.

This experience has also taught me to accept my ineptitude with learning scientific species names, yet also to embrace my strong sense of *biophilia*. Renowned biologist and naturalist E. O. Wilson uses this term to refer to humans' innate affinity for life in all its forms. As someone born and raised in the urban concrete expanse that is Los Angeles, California, my biophilia lay mostly dormant for much of my life. Like a fresh rain that breathes life back into the cloud forest after a dry spell, restoring it to lushness, my experience with NI has awakened my biophilia from its slumber. Now I find myself pausing often to notice the life processes all around me, all the time, whether I am trekking through a forest or walking around in a city. This stopping to smell the roses, listening to the distant melody of a songbird, or gazing upon a giant tree while wondering how many human generations lived in parallel fills me with a sense of peace and well-being. It also functions as a positive reinforcement loop: the more I pause and absorb, the stronger my biophilia grows, and as it does, the more I notice life. My growing propensity for spotting and admiring life around me, especially in its most subtle expressions, may not be at the level of an eagle-eyed nature guide, but it is a cherished gift that I hope will accompany me wherever my own life takes me.

Finally, although I did not mean this to be an exhaustive account of how my experience with Nectandra Institute and our community partners has shaped me and my conservation ethic, I would like to shine the spotlight on a phrase that resonated with me immediately upon hearing it for the first time, *"For our children and our children's children."* Costa Ricans we work with have used these words to encapsulate their own motivation for protecting the area's forests and watersheds. The words, simple yet poetic, inspire me because they effectively demonstrate our community partners' long-term vision. Many of them followed these words with an acknowledgement that they will not live long enough to see the fruits of their restoration efforts. Yet, they persist in helping the forest grow back, which will take decades. They do so motivated by a desire to bequeath a healthy and livable world to the unborn. It is a motivation that is equal parts self-serving and selfless; a desire to leave a lasting legacy and a simultaneous show of respect for the well-known tenet held by many conservationists: that the planet's natural wealth is not ours to keep; it is merely on loan to us from future generations.

— Luis Villa —

Ecosystem Services: Experiences and Thoughts

In November of 2017 the 5th International Conference on Ecosystem Services in the Neotropics took place in Oaxaca, Mexico. The conference presented an opportunity for 300, mostly academics and representatives from the public sector, NGOs, local communities, the media, to share, converse and reflect upon this important topic.

The talks, symposia, posters, and activities focused on various initiatives for the valuation of ecosystem services throughout Latin America. They also highlighted the challenge of implementing public policies to bridge the often conflictive relationship between society and nature, as well as the tools provided by economics for the effective valuation of ecosystems.

NI was invited to participate as part of a special conference session focusing on examples of community-based ecosystem services valuation schemes in Mexico and Costa Rica. The case studies presented during this session will be published in an upcoming edition of the journal *Ecosystem Services*.

The main topic Payment for Ecosystem Services (PES) national programs mostly use a top down approach to increase forest cover, e.g. the one carried out by the Costa Rican National Forestry Financing Fund whereby landowners are paid to set aside forest for conservation. However, these types of programs may not fit all situations, necessitating strategies that complement, rather than substitute, traditional, centrally-run PES schemes.

Take for example the cases where land possession is not clear-cut, consisting of only *de facto* possession by indigenous or local communities that have conserved ecosystems for generations. Other cases illustrate the relevancy of innovative ecosystem service valuation schemes to restore land with a high degree of ecological fragmentation. Costa Rica's Balsa River watershed, for example, is largely an agroscape dotted with small patches of vegetation that are not within the legal definition of a forest (greater than two hectares), despite being important refuges for local biodiversity and sites with hydrological importance. ASADAS are protecting these important areas, restoring them and connecting them thanks to NI's Eco-Loan Program.

The concept of ecosystems services can be a powerful tool for avoiding environmental deterioration. A convincing example of this is the beneficial symbiotic relationship between Azteca ants and *Cecropia* trees that helps to control plagues in coffee. Another example discussed was the proliferation of severe health epidemics in India associated with the population decline of scavenger birds. Nature also provides us with more subtle benefits, such as the sensation of peace and wellbeing that can come from a walk through the forest. (See article by Luis Villa in this newsletter). Despite the evidence supporting our absolute dependence on natural capital for our survival as a species and civilization, this has not been sufficiently internalized by the public or decision makers. The great challenge is to

transcend beyond the walls of a conference hall or the words of a scientific paper and reach out to a larger audience with strategies that effectively communicate and build understanding for the multiple services offered by ecosystems as a gift to humanity.

—— *Manrique Esquivel* ——

Manrique is Nectandra Institute's biologist on staff and coordinator for ecological restoration projects.

Recent News Highlights

July Our partners oftentimes recruit school children, company employees and other groups of people to participate in forest restoration efforts. This month's tree planting activities at their restoration sites this month were no exception, as 70 representatives from the Communities Conservation Water Resources League (Liga CUENCA, its acronym in Spanish) and CoopeAlfaroRuiz helped plant over 250 trees on three different properties purchased by eco-loan recipients.

August New NI volunteers from University Studies Abroad Consortium began their three months internship with us. U.S. students Teresa and Andrew helped monitor our stream water monitor quality and document the progress of the emerging forest on eco-loan financed properties. They followed the footsteps of over 30 young volunteers, including 14 through USAC, providing invaluable support in advancing the Institute's mission of cloud forest conservation.

September NI staff obtained drone aerial footage of Finca Tulio, a 24-acre property recently purchased by the community water management association of Las Brisas. Finca Tulio was one of the last "missing pieces of the puzzle" needed to bridge the gap between lands that are already protected. Soon, the vegetation will start to regenerate an emerging forest, both naturally and with help from the local community. It was purchased to increase the forest that protects Las Brisas' drinking water source. It is commendable to see this community's initiative and the efforts being made to preserve and ensure high quality water for current and future generations.

Now in its 10th edition, New Culture of Water Month is an annual celebration created by NI to raise awareness for conservation of forests and protection of water resources — through a series of educational, artistic, recreational, and cultural activities, including the inaugural celebration, the New Culture of Water Queen Pageant, featuring candidates wearing dresses made from recycled materials, and the decathlon format CRECER competition, which tests the ecological knowledge of teams of students from several of the watershed's different grade schools .

October NI and FEDAPRO (a federation of water management associations in the canton of Naranjo and one of our Eco-loan partners) were invited to present on Finca Sembrando Agua at Naranjo's Liceo Experimental Bilingüe. Some of this bilingual high school's students won a scholarship from a local NGO that requires the students to engage in volunteer community work. The students fulfilled this requirement by dedicating themselves to ecological restoration efforts on FEDAPRO's 21-acre property. The enthusiasm was such that non-scholarship students also signed up for future tree planting and other restoration work.

November 2017 Hardworking Guillermo and Teresa, finished their great volunteer work. They braved inclement weather in the field. We are very grateful for their valuable contributions to our conservation efforts.

A drone flight was conducted over the Nectandra Cloud Forest Preserve to obtain base line images for future comparison. The aerial footage obtained shows us a glimpse of the forest's central role in capturing moisture from the atmosphere. This natural sponge made up of lush forest vegetation helps reduce surface runoff, facilitate groundwater recharge, and regulate water flow from springs and in rivers.

December 2017 NI participated in the annual year-end celebration by Liga CUENCA. The gathering included a series of bonding activities, a screening and discussion of a video on demonstrating personal leadership, a farewell to the Institute's Luis Villa and introduction of new staff member Pablo Richard. Nectandra was a catalyst in the formation of Liga CUENCA, which unites several community water management associations in the upper Balsa River watershed for the purpose of promoting the protection and conservation of the water resources for current and future generations.

Annual tree growth measurements and semiannual time lapse photos were obtained on Finca Ocotea. This nearly 250-acre property belongs to Asociación Fuente Administradora de los Mantos Acuíferos de Alfaro Ruiz (AFAMAAR). AFAMAAR purchased this land and placed it under conservation and restoration in 2009 thanks in large part to an eco-loan from Nectandra Institute.

— Reported by Pablo Richard —

Pablo recently joined NI as Director of Administration and Development after thirteen years at the University for Peace and three more at the Organization for Tropical Studies. He is a biologist, nature guide; he holds a Master's degree in Responsible Management and Sustainable Development.