the National Biodiversity Institute of Costa Rica

How to save tropical biodiversity

by Daniel H. Janzen

How does one save tropical biodiversity? Save it, come to know what it is, and put it to work sustainably. Have the residents conduct all three sequential steps in an overlapping manner, at a specific site and countrywide.

For the past several decades of concern about the tropics, these three steps have been viewed as the responsibility of the conservationist, the taxonomist, and the businessman. Each of these professions has marched to its own drummer, generally viewing the others as passive supporters or enemies. The time has come for serious collaboration, so as to move the imminent extinction of tropical biodiversity from being a subject of extra-tropical discussion to being a matter of daily tropical concern.

Seventy-five percent or more of the world's biodiversity is arthropod (see Wilson [1985, 1987, 1988]). While these arguments apply to all areas of biodiversity, they apply especially to arthropods. Entomologists will be affected very strongly by the pending loss of tropical biodiversity. If we, the thousands of academic and working entomologists, do not help the woefully few conservationists and businessmen in their endeavor, then we will have no one to blame but

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The main administration and collections building of the Instituto Nacional de Biodiversidad on the outskirts of San José. It is a remodeled construction machinery warehouse.

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ourselves when the very things that give meaning to our lives are swept from the tropics. I plead for the adoption of a new goal-directed behavior by entomologists, for a personal contribution to the conservation of tropical biodiversity into perpetuity, even when it means the partial neglect of some traditional entomological goals.

So what, specifically, do we entomologists do? What do we like doing and what are we good at? Among other things, we are good at coming to know what has been saved—the second stage mentioned in my introduction.

Systematics: An Example of How to Help

In the eighteenth century, Linnaeus started us down a long scientific path (Usinger 1964). He responded in a very goal-directed manner to society's very real need for a system of nomenclature that would allow us to communicate about our beasts. He performed an applied service of great value to all of us who use information about organisms, which is most of modern society. However, the two and a half centuries that followed Linnaeus also have been the last sprint for the finish line in the great race to bag up and parcel out to humanity the earth's natural resources.

During those centuries, we entomologists have recognized and cataloged the earth's arthropods at a pace set largely by the agricultural and medical needs of the species-poor temperate zones and by the proclivities and curiosity of a small body of professionals with exceptional enthusiasm about cataloging small, diverse objects. Linnaeus' global goal-directed behavior quickly became focused on bioproducts and diseases that have been with us for millenia, and on those regions and social systems of the globe that generate a hefty profit from such a focus. Our curiosity—generally expressed in many scientific journal publications—has chugged along at its own rate and has not been financed any better than most other expressions of curiosity.

Tropical arthropod biodiversity was first the enemy of development, and then it became the victim. Humanity is pulping the Library of Congress to meet a newsprint shortage. There is only one way to halt the process. Show the world that this elimination of biodiversity represents a hefty loss, and then begin to make biodiversity generate a hefty return. To do that we must have the ability to locate and read the books.

When there are only a few hundred books in a library, only a few dozen users, and only three tabletops on which to use them, this taxonomic ability need be no better developed than that in any of our own offices. That is to say, if the world were reduced to cotton, boll weevils, and Texas, systematics could largely be tossed out the window and we could drink gossypol tea for breakfast. But the world is not Texas. Costa Rica is about the size of the Texas panhandle and contains at least 500,000 species of organisms, at least 365,000 of which are arthropods (table 1). This is probably about 4 percent of the world's species.

So how do we locate the books in a huge and complex library? Get call numbers on them, organize them on the shelves, and form a computerized catalog. How do we use the books? Open the library twenty-four hours a day, have a large staff of reference librarians, have generous lending policies and lots of duplicate copies, have very good xerox machines, and put a lot of people to work reading, reporting, and discussing what is in the books. And even write new books. This requires more than a budget. It requires a shift in priorities and attitudes on the part of the entomological community. If systematics wants serious funding from society, then systematics must wed itself to a process and product that society values seriously.

Cost of a Countrywide Arthropod Inventory

Costa Rica can be used as a specific example. This country, which covers fifty thousand square kilometers, has at least 365,000 species of arthropods and most of the climatic and topographic diversity found from southern Mexico to lowland Panama. To inventory such a fauna and put the records in an accessible format, we need 1,825 person-years of work (or 18.25 years of work by one hundred doctorate-level taxonomists) after the bulk of the specimens are mounted, labeled, and crudely sorted to alpha species or alpha genera. At a minimal cost of one hundred thousand dollars per year in salary, benefits, capital investment, maintenance, and overhead for one taxonomist and an assistant with collections, the initial

A Guanacaste Conservation Area blacklight draws a tiny fraction of Costa Rica's 350,000 species of insects that the parataxonomists and INBio are inventorying. They range from the familiar yellow Eacles imperialis to the exotic, long-tailed Copiopteryx semiramis.

price of the inventory is $182.5 million. Putting the specimens in the drawers where the taxonomist can work on them in the first place will cost another $30 million spread over three decades. This is 48.25 years at a cost of $212.5 million merely to identify and organize just 4 percent of the world's arthropod biodiversity.

No matter how appealing such growth in tropical systematics may seem, it's too expensive and too slow as a major first step in saving tropical biodiversity (Janzen 1985, Holden 1989). We have, at best, a decade to get the biodiversity library in order in Costa Rica, if it is to be used to put biodiversity to work for society. Although we may have a few years more in a few other tropical countries, in most the demolition team is already on the site and no time remains.

We are confronted with the classic administrator's nightmare of having to choose between applying shrinking resources to the familiar status quo (we all know how to prepare monographs and curate our collections), and abandoning some of the status quo and moving into the vague unknown—ideally with financial support from other sectors of society. I feel that we have no choice but to make the second choice. If we entomologists do not make insect biodiversity an important part of tropical society, society will sweep tropical insect biodiversity into oblivion.

What Do We Have to Work with in the Tropics?

Who are the entomological troops, what do they know, and what weapons do they have? The realist answers, "We are a demoralized and fractious body of doctorate-level insect systematists, largely concentrated in the temperate zones with overcrowded and underdeveloped facilities, little global leadership, and less social approval." As Wilson says, ". . . you get people who are less bold. I can't imagine a first-rate molecular biologist taking 'no' for an answer if he has a new idea in cancer research and he's looking for funding. But by now someone in insect taxonomy may be quite used to being told 'no' " (Holden 1989). We entomologists feel that the problem of saving tropical biodiversity is too big, too complex, too expensive, and too far away. And we feel that nobody really uses the tropical insect biodiversity library anyway. There appears to be little or no standing budget to redirect. The bright and curious entomologists move into other more challenging areas of society. Systematic arthropodology is in senescence. Without a fundamental change, the existing society of entomologists cannot inventory the arthropods of Costa Rica or any other tropical country in a decade. Continued bleating for more money and more taxonomists falls on society's deaf ears for the simple reason that society funds only that which gives an evident return on the investment.

However, when at war, you take the resources at hand and apply them to the situation. Doctors drive tanks and English professors run weather stations. You

don't ask how long it will take to build an airstrip. You ask how many days before the planes will arrive, and then you find the resources to build it in those six days—or you lose the war.

For Costa Rica, ten years is a generous estimate of the amount of time before social pressure builds up to a level that will overwhelm the conservation system now in place, unless that conservation system is a highly productive sector of society. If Costa Rica's biodiversity is not firmly introjected into the minds and pocketbooks of Costa Rican society within a decade, the bulk of it will go into constructing cornfields and Miami lawn furniture.

Fifty million dollars is a cost that does not cause international budgeteers to levitate out of their chairs. So how do we inventory Costa Rica's biodiversity for $50 million in ten years, instead of $212 million in fifty-eight years? How do we do it without absorbing all the global funds currently available for arthropod biodiversity management resource? How do we do it so that the effort lives on through generations? The answer is that we in the United States don't do it. What we do is collaborate with, and facilitate, the Costa Ricans in their own efforts to do it.

The Costa Rican National Biodiversity Institute

Beginnings. From 1986 to 1988, while I was searching for international major funding for Guanacaste National Park in northwestern Costa Rica (Allen 1988, Janzen 1988), it was clear that the developed world's policymakers viewed working with conserved tropical biodiversity as regal (see Wilson & Peter [1988] and Eisner [1990], for example). However, the absence of an actual, large-scale example of conserving biodiversity through use was conspicuous. There was no working model, pilot project, or down-to-earth idea generator. Speeches about biodiversity were full of policy hopes and not concrete actions.

I returned to Costa Rica in October 1988, intent on saying to Costa Ricans that if they would hold their collective hand up and say, "We agree that we will manage our biodiversity into perpetuity," I'd bet the developed world would provide the funds. However, I discovered that a diverse group of Costa Rican biologists, government administrators, and conservationists had met the month before to express very strong frustration. Their highly fragmented and largely independent efforts in conserving biodiversity through management were producing only minor results. They themselves had come to the conclusion that it was the natural moment for the collaborative effort that the international community sought.

Since that September in 1988, Costa Rica has mobilized (Lewin 1988) and formed the new National Biodiversity Institute, or INBio (Instituto Nacional de Biodiversidad). INBio is a private, legally registered, nonprofit, public service association (Tangley 1990) that is working for the conservation of Costa Rica's biodiversity by understanding what it is and by facilitating its nondestructive use by all sectors of society. Its board of directors and its assembly have representation of each sector of Costa Rican society that makes intensive use of biodiversity or is responsible for its management. Its director, Dr. Rodrigo Gámez, was the former director of the Institute for Cell and Molecular Biology at the University of Costa Rica. He moved from the university milieu into the public sector in direct response to a social plea for the involvement of academia.

INBio now has its own buildings on the outskirts of San José. The buildings are long-term temporary, for use until the major facility is constructed on a much larger site specifically to meet the needs of INBio into perpetuity. The buildings house what were the biology library, herbarium, and insect and bird collections of the Museo Nacional de Costa Rica. Additionally, they contain what were the human and hardware resources of the Conservation Data Center (formerly in the offices of the Fundación Neotrópica and Fundación de Parques Nacionales), now transformed into the beginnings of the National Biodiversity Data Base. The natural history collections of the Universidad de Costa Rica and the Universidad Nacional have been incorporated to the degree that space permits. Finally, there are the very large and expanding arthropod and plant collections being generated by the National Biodiversity Inventory.

Table 1. Estimated numbers of species of organisms in Costa Rica (unpublished data)

Species	Estimated no. in Costa Rica
Arthropods	365,000
Other invertebrates	85,000
Bacteria and viruses	35,000
Plants	10,000
Fungi	2,500
Vertebrates	1,500
Total	500,000

Administratively, INBio is the National Biodiversity Inventory (including the collections), the National Biodiversity Data Base (including the library and research registry), and the Public Biodiversity Information Service. The intent, spirit, and fact of INBio is to aggregate and focus Costa Rica's quite diverse efforts and administrations on the central goal of knowing what is biodiversity, putting it to work sustainably, and thereby contributing in a major way to saving it.

As Costa Rica works toward countrywide management of its entire natural resource endowment, it is becoming clear that the real shortage is not money as much as human resources that have been educated in the technology and philosophy of such a complex management task. INBio has accepted a major role in both facilitating and directly conducting a major portion of this educational process, primarily through course work and apprenticeships in the areas of censusing, organizing, manipulating, and distributing biodiversity information. This information ranges from knowledge of specimens and living populations to data bases and library resources. Manipulation of this information ranges from producing identification systems (field guides, lectures) to teaching it to teachers and providing it to the government or a commercial user. Above all, the goal is to make biodiversity information and understanding an everyday part of Costa Rica's social, intellectual, and economic fabric.

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Regionalization. The appearance of INBio as a Costa Rican national institution automatically generates the question of why not be regional, at least to the extent of covering Central America. First, this is not the time in history to attempt any kind of top-down regionalization of a Costa Rican institution; there are more pressing concerns at the regional level. Second, regionalization at the beginning creates an institution with no home at all, an experience through which many neotropical regional teaching and research institutes have had to live. Third, INBio's success will depend not only on such concrete results as the biodiversity inventory, but also on the ability of various sectors to make use of the accumulating information; Costa Rica is the only mesoamerican country to date with a nationwide commitment to sustainable management of its natural resources. Fourth, the new kind of beginning that INBio represents needs a friendly government and private environment in which to evolve. INBio has chosen a nice day to get the first airplane off the ground; later on we can evolve something that can fly through a hurricane.

Financing. The first two years' financing of INBio's planning and development has been small ($5.18 million) in comparison with budgets for such an institution in the developed world. It is adequate as a beginning and drawn from private foundations (MacArthur, Pew, Noyes, Wege, Swedish Society for the Conservation of Nature, World Wildlife Fund—United States, The Nature Conservancy, British Museum (Natural History), Smithsonian Institution, Fundación Neotrópica, Fundación de Parque Nacionales), private donors, and governments such as Costa Rica (the Ministry of Natural Resources, Energy and Mines; the Central Bank), the United States (the Agency for International Development, the National Science Foundation [NSF], the U.S. Department of Agriculture–Agricultural Research Service [USDA–ARS]), and Sweden (Swedish International Development Authority [SIDA]).

The anticipated long-term financing is a novel partnership between the developed world and Costa Rica. With a one-time $50 million capitalization and operating donation from the developed world, can INBio become fully financed indefinitely with a debt-for-nature swap? A major portion of the $50 million would be used to purchase about $150 million (face value) of Costa Rican international commercial debt on the open market. The purchased debt then would be forgiven by the purchaser (INBio). In return, the Costa Rican Central Bank would issue the debt's face value in dollar-denominated, Costa Rican government, twenty-year bonds to an INBio trust fund (*fideicomiso*). These bonds pay INBio 3.33 percent annual interest in local currency at the current rate of exchange. INBio therefore would receive $5 million (in Costa Rican colones) in annual operating and capitalization expenses. This represents $50 million over ten years and leaves the remainder of the income from the trust fund for the activities that develop at INBio. The principal of the trust fund serves as an endowment indefinitely. However, this funding comes

from the public sector, once again emphasizing that the public sector can correctly demand products from INBio in return.

This process requires two missing resources: the donor and the willingness by the Central Bank. The Central Bank periodically expresses its willingness to consider this financing matter seriously. In March 1990, it conducted a small debt-for-nature swap with INBio funds. However, the donor is currently the subject of an intense search.

The Costa Rican Arthropod Inventory

The staff, physical structure, administrative framework, and minimal funds (with hope for major funding) that constitute INBio must perform two other major components of the action: the arthropod inventory and phytochemical prospecting. For the inventory, the game plan is to generate on-the-job a small army of Costa Rican "parataxonomists" to handle the bulk of the fieldwork—that is, to put most of the arthropods in a usable form. Simultaneously, INBio enlists you as collaborators and teachers with and for the on-the-job generation of an INBio staff of Costa Rican apprentice curators. And we publish at INBio and put the information to work in Costa Rica. What the developed world gets is a by-product of what Costa Rica is doing for itself, albeit a very valuable one.

The Parataxonomist. Costa Rica is rich in underutilized human resources. Virtually all members of Costa Rica's population of 2.8 million who are old enough can read and write. But hundreds of thousands of people are at a level of education and training far below their intrinsic capacity. The parataxonomists are selected by applications and highly competitive interviews. The potential parataxonomists are park guards, farmers, ranchers, housewives, high school students, forest rangers, game wardens, government administrators, and others. Most applicants have a rural background and education level somewhere between sixth grade and one to two years of university. They either are already salaried civil servants or are newly employed by private, nonprofit conservation organizations.

The successful applicants take an intensive, full-time five- to six-month course. It covers what a person really needs to know in order to be an independent, full-time arthropod surveyor, collector, and preparator under rural conditions in a tropical country. Additionally, there is heavy stress on the significance of INBio activities for Costa Rica's development, as well as biodiversity conservation. In effect, the basic parataxonomy course is a vocational course. The teaching assistants are parataxonomists who distinguished themselves in previous courses. The course schedule is ten- to fourteen-day periods of instruction interspersed with short breaks. The basic course is followed by on-the-job training, occasional formal four- to six-week advanced courses in particularly difficult groups of insects, and opportunistic apprenticeship to professional national and international taxonomists and apprentice curators at INBio.

The parataxonomists are not to be thought of as embarking on the first steps to becoming a doctorate-level entomologist (even though on rare occasions such may be the case). Rather, they are learning a vocation. It is their genetic and cultural offspring who will enrich the resource pool for the next generation of in-country doctorate-level scientists, university professors, and senior government administrators. The parataxonomists view their new vocation as an enlightened step upward from a static position in society to a position with great vertical and lateral mobility. The starting salary and social benefits of a trained parataxonomist currently equal approximately seventy-five hundred dollars per year, a highly respectable middle-class salary under rural circumstances.

A steady-state pool of one hundred to two hundred parataxonomists working through INBio for about ten years can put well over 95 percent of Costa Rica's arthropod biodiversity into INBio's National Biodiversity Inventory. The ten-year period begins when INBio receives its $50 million for the long-term financing that was mentioned earlier. The first class of sixteen parataxonomists graduated on 25 July 1989; another seventeen graduated in September 1990. Substantially more parataxonomists can be trained per year as soon as INBio obtains permanent funding.

A century-old cattle pasture of Guanacaste Province, now replanted to young pochote trees (Bombacopsis quinata). The pests of these trees are the subject of some of INBio's taxonomic, ecological, and integrated pest management studies.

The parataxonomists work out of biodiversity offices. Currently there are sixteen biodiversity offices. The offices are distributed over the country's eight conservation areas (*Area de Conservación* or AC). These ACs administrate about 25 percent of the country and include almost all wildland areas that have been conserved for biodiversity. A full-time parataxonomist produces, conservatively estimated, an average of about two hundred properly pinned or point-mounted specimens per day for twenty days of the month, or four thousand specimens per month for eleven months of the year. (These estimates are based on the twenty-eight parataxonomists currently at work.) Accordingly, thirty full-time parataxonomists produce at least 1,320,000 million pinned specimens per year for INBio. Labeling and sorting of this material to major groups at INBio is done by the apprentice curators and their assistants. (The parataxonomists are also active plant collectors and will move into other groups as resources permit.)

Parataxonomists are more than standard technicians or collectors, just as paramedics are more than ambulance drivers. Not only are the parataxonomists a distinctively motivated and intelligent subgroup selected from the applicants, but also they almost immediately form a distinctive group with a tight common bond. Despite the fact that they work at far-flung points of the country, when they bring their specimens into INBio they are very curious about what adventures are befalling the other parataxonomists and how successful they are with their collecting. They are also driven by a desire to demonstrate to their former workmates, who did not select such a responsibility-rich vocation, that they can handle the task.

Their work extends to more than their peers. There has been a growing tendency to enlist the help and enthusiasm of neighbors and school children to collect insects and think about the forest they live in or next to. I should add that NSF has responded to the parataxonomists' outreach efforts by allowing each parataxonomist a small discretionary fund to subsidize these activities. Finally, it deserves notice that the parataxonomist's intellectual gambit is open-ended; all of entomology and botany is laid out in front of a parataxonomist. The international visitor who can communicate finds them to be veritable sponges for biological information.

The Apprentice Curators. The apprentice curators usually have Costa Rican bachelor of science or bachelor of arts degrees in biology, have expressed a strong interest and ability in doing taxonomic work with a particular group of arthropods and within the philosophical framework of INBio, and are encouraged to work

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closely with international taxonomists. Some may seek higher degrees at international institutions later, but all are expected to develop at INBio to where they can carry out the daily work of a doctorate-level taxonomist who is participating fully in a national inventory. Like the position of the parataxonomist, the apprentice curatorship is a new category of employment. It was invented to meet the needs of INBio on the one hand, and the urgency of the saving biodiversity on the other. We do not have the luxury of taking decades to train dozens of doctorate-level scientists from foreign lands to handle the specifics of INBio's challenge. It is indeed ironic that the advances of many major museums of the developed world in the past century have been based on a solid mix of doctorate-level staff and less formally trained staff with a profound interest in the taxonomy of specific groups, but today many entomologists have come to view the downtrend in the production of doctorate-level taxonomists as a major hurdle in handling the world's biodiversity.

The Taxonomic Process at INBio. As a huge body of specimens in some major insect taxon accumulates at INBio, an apprentice curator works diligently to sort it to morpho-species and other groupings. Common sense and some easily accessible literature are the major tools.

At this time, INBio invites an international taxonomist to work with the specimens along with the apprentice curator. INBio hopes to be able to offer an expense-paid trip to Costa Rica or convince the taxonomist's administration to provide the trip. The taxonomist and the apprentice curator divide the task into three parts. First, there is a large set of Neotropical species that almost any specialist can identify immediately (irrespective of whether some future Neotropical generic or subfamily revision may later make the name synonymous with an older name based on a type from Brazil or Mexico). These species are built into the INBio reference collections on the spot, using the legwork of the apprentice curator and the INBio technicians, thereby minimizing the time investment by the specialist and updating the apprentice curator's understanding of his group's taxonomy.

Second, there is a group of species that the specialist recognizes as needing descriptions, irrespective of their generic placement. Third, there is a set of species that need to be compared with types, evaluated for generic revisions, and sent to other specialists before they can be identified or correctly placed in a higher taxon. The specialist and the apprentice curator invest their energies in these second and third groups, deciding between them what specimens and species will be loaned to whom and for what, and how best to attack the question of getting them taxonomically clean.

The International Taxonomist. *The Breaking of Tradition.* In whatever manner this major amount of work is partitioned, the goal is to load the specialist with only as much work as he or she wishes and feels free to accept. The apprentice curator and INBio work to increase the in-country human and financial resources to do as much as possible in Costa Rica, but with the guidance of the specialist. Viewed this way, traditional traumas about artists' salaries, page charges, deposition of types, collecting permits, loan bureaucracy, scientific imperialism, working facilities in far-away lands, permanent curation, and many of the other bugaboos of tropical taxonomy begin to fade away. These problems are replaced by a new, refreshing set of challenges: learning Spanish, learning how to be a master to an apprentice who lacks what we have come to expect in university training, doing regional or even more local taxonomic work, allowing and guiding others to have the thrill of discovery, working as a team, fitting priorities into a foreign governmental and cultural framework, and working toward a goal other than curiosity. But most important, we move tropical taxonomy out of the doldrums.

For this kind of national inventory to attract international taxonomists with high enthusiasm and ability, INBio must work at making collaboration with international taxonomists as effortless as possible. It also requires that the international taxonomists and their employers back home accept a quite different reason for going on a "collecting trip" to a tropical country. It means keeping your eye on the goal—the rapid attainment of self-reinforcing taxonomic literacy by a developing tropical country through the use of in-country resources. Such a country is, by far, the best kind of future partner to have in the global management of the challenges and

benefits of biodiversity. However, facilitating the appearance of such a country demands a changing view of the tropics by the international science community. The tropics have to be viewed as a partner in a venture rather than a resource to be harvested.

A recent example is illustrative. In 1988, NSF granted thirty thousand dollars to the University of Pennsylvania to facilitate participation of the Entomology Department of The Natural History Museum (TNHM) (formerly, the British Museum [Natural History]) in the entire INBio inventory process described above. From 1988 to 1991, ten specialists (I. Gauld, S. Brooks, M. Scoble, L. Mound, C. Lyall, N. Stork, P. Eggelton, D. Hollis, J. Noyes, L. Pitkin) came to INBio and since have become deeply involved in INBio's teaching and inventory programs. They did not come to Costa Rica on a collecting expedition. Rather, they came to introduce themselves to the challenge of this kind of in-country development of human resources and to be major participants in it. Their visits have resulted in a several-million-dollar proposal to the European community for collaborative research between TNHM, INBio, and the Universidad de Costa Rica. These TNHM scientists also have co-taught with faculty from U.S. and Costa Rican institutions in two NSF-supported advanced courses for the parataxonomists in 1990–91 (A. Solis, J. Powell, L. Pitkin, P. Hanson, I. Gauld, J. Noyes). The course coordinators and assistants for these advanced courses are INBio apprentice curators in their respective areas.

In a similar vein, an outstanding opportunity now exists for a full-scale taxonomic attack on the more than two thousand species of Costa Rican Pyralidae by at least five international specialists in collaboration with INBio personnel, coordinated by A. Solis of the USDA–ARS Systematic Entomology Laboratory (SEL), and bringing together financial and human resources from NSF, the Smithsonian Institution, USDA–ARS–SEL, INBio, several universities, and the government of Costa Rica. Both of these international interactions are far beyond the traditional collecting trip to the tropics.

Financing. In a developed country, activities such as INBio's are supported by taxation through a federal agency. However, the debt-for-nature swap allows governmental budgeting of INBio with funds that otherwise would have been paid as interest on Costa Rica's international debt and therefore exported as U.S. currency.

Isidro Chacón, INBio's former curator of diurnal Lepidoptera, Saturniidae, and Sphingidae, explains to a parataxonomists' class that the six specimens of Eurytides pausanis (a swallowtail mimic of Heliconius cydno) that they have just collected are the first Costa Rican specimens with locality data and the second to eighth specimens in INBio's national butterfly collection.

The international taxonomist may play some unexpected roles in the financing of an international effort such as INBio. For example, I. Gauld, a TNHM ichneumonologist, has been a major participant in the Costa Rican national biodiversity inventory since 1984 (see Gauld [1988]). "I spent three years of my life doing the ophiine ichneumonids of Africa [a tome the size of a telephone book for a medium-sized city] and I get three reprint requests. When I work in Costa Rica, people actually use what I do." I. Gauld and P. Mitchell are revising the 145 species of pimpline ichneumonids collected in the past five years in Costa Rica. In early 1989, Salomon Brothers debt-trading firm in New York performed a $24 million debt purchase with a $3.5 million donation from the Swedish government for the Guanacaste National Park Project and charged no fee (Anonymous 1989a). Gauld and Mitchell decided to name thirteen species of Costa Rican pimpline wasps after those members of Salomon Brothers who had contributed greatly to saving the wasps' habitats by performing the debt-for-nature swap. (Ironically, these particular pimpline wasps happen to be parasites of Linyphiidae, or "money spiders" in both English and American vernacular.) Soon the chief executive officer of Salomon Brothers, John Gutfreund, started talking about having a wasp named after him. Next, Gauld found his new drawing of *Eruga gutfreundi* adorning an article in *Institutional Investor* (Anonymous 1989b).

A third-instar caterpillar of Copiopteryx semiramis on its host plant (Manilkara chicle) in the Guanacaste Conservation Area. Roberto Espinosa, today an experienced parataxonomist and caterpillar collector, discovered the Costa Rican host of this moth in 1983.

This type of publicity was a first for TNHM, as well as for parasitic wasps. It also meant another free-of-charge debt-for-nature swap, this time for INBio. These events constituted the construction of a mutualism. For Salomon Brothers, cash is not a scarce resource, but immortality is; for INBio, TNHM, Gauld, and Mitchell, bestowing immortality is an everyday event, but cash is a scarce resource. On just one current INBio $615,000 debt-for-nature swap, Gauld's drawing of *E. gutfreundi* was worth at least $187,285 to the INBio endowment.

The New Environment. The community environment in which the international taxonomist works in Costa Rica has its good and bad points. Public education levels are high, crime is low, the population is healthy, and communicable diseases are scarce. The population is skewed toward being young and not xenophobic; the contacts of today will be the decision makers within one or two decades. However, the visiting taxonomist also enters a system that is not much cheaper to live in than the United States, yet one's peers are surviving on less than a third of the salary and double-digit inflation. The rewards of collaboration are not those of a colonial life-style.

The Challenge of Faunistic Studies. Perhaps the single largest psychological challenge facing the international taxonomist who participates in the inventory of Costa Rica's arthropods is the change from doing revisions of genera or higher taxa to doing faunistic studies. Another major change is that of heavily investing in pragmatic output rather than research on phylogenetic relationships. This change in emphasis requires both a personal change and a change in peers and employers. Major funding agencies (such as NSF and the U.S. Agency for International Development [USAID]) recently have started considering faunistic efforts of the nature

described here for Costa Rica as mainstream, but this does not mean that university and museum employers will see it that way.

Faunistic studies have well-known difficulties. However, they also have some distinctive advantages when they are based on massive collecting in all seasons and habitats. Long series of specimens ranging over extensive microgeographic variation are very helpful in understanding what is intraspecific variation versus what is interspecific variation. Massive collecting efforts result in many supposedly allopatric and questionable species being found to be sympatric and unambiguously distinguishable in some small overlapping parts of their ranges. Massive collecting also ensures enough material for everyone, and it greatly reduces the frequency of uniques. When coupled with rearing, massive local collecting may even allow the taxonomist to separate resident species from waifs. For example, in the ten thousand-hectare Santa Rosa National Park in the Guanacaste Conservation Area in northwestern Costa Rica, there are thirty breeding species of saturniids and at least five that arrive as waifs from neighboring rainforest areas (Janzen 1986); these five species would have been recorded as residents by any traditional collecting expedition.

However, cleaning up the taxonomic status of Costa Rican insects does not mean ignoring other tropical areas. A glance at the distribution maps in any major faunistic work (for example, Powell [1973], Gauld [1988], Lemaire [1988]) usually shows 50 percent or more of the species in Costa Rica to have extremely wide species distributions (see Janzen [1986]) that cover twenty to eighty degrees of latitude and many Neotropical countries. It is also clear that taxonomic literacy will arrive throughout the Neotropics through home-grown and home-supported efforts in particular places. Faunistic studies of Costa Rica will contribute to inspiring similar efforts throughout the remainder of the Neotropics, as well as go far in providing data toward an overall attack on Neotropical taxonomic problems.

"For INBio ... bestowing immortality is an everyday event, but cash is a scarce resource."

Putting Biodiversity Information to Work: Phytochemical Prospecting

As biodiversity information accumulates in INBio, in its specimen drawers, herbarium cabinets, data bases, and personnel, it has to be put to work for Costa Rican society. An example is phytochemical prospecting, which is the search for phytochemicals and other allelochemicals in animals that intoxicate humans—their enemies and friends—in various ways and degrees. Phytochemical prospecting has a long and venerable history. In the last two decades, however, this interest has waned because of the ability of humans to make synthetic chemicals, the rapidly widening gap between people and nature, and the seeming security of knowing exactly what is in the potion you drink. In the tropics, the spectre of economic imperialism, wars, chaotic bureaucracies, sources that vaporize overnight, and unreliable taxonomy have further decreased the commercial interest in phytochemical prospecting. On the other hand, in the past few years the opportunity to manage the genetic information that programs for useful phytochemicals has moved into in a seemingly limitless growth phase. The world at large has come to realize that there are very real reasons to seek a diverse array of phytochemicals for everything from pest control to hormones, altered food coloring, and attachments to AIDS viruses. And the cost of discovery, testing, and marketing of such chemicals has moved into the vicinity of $100 million per chemical.

In effect, Costa Rica is a corporation covering fifty thousand square kilometers, with twelve thousand square kilometers of greenhouses containing about five hundred thousand species, and three million caretakers and shareholders. The INBio national inventory tells us what is in the greenhouses, which are otherwise known as the national parks. Costa Rica desperately needs a mechanism to move into joint ventures with commercial entities from the developed world that find, develop, and market products of wild biological origin. Such a joint venture is necessary because the technical aspects involved in developing and marketing these products are too costly and complex to be handled by an analogue of the biodiversity inventory of Costa Rica's organisms that is being conducted at INBio. Once the partnership is established, a portion of the benefits to "Costa Rica Ltd." should then contribute significantly to the overhead for the national greenhouses and the

"The tropics have to be viewed as a partner in a venture rather than a resource to be harvested."

corporation itself. It is striking that, for example, almost none of the enormous profit from coffee and cola drinks flows back into the management and conservation costs of the tropical forests—the same forests that spawned the plants that gave birth to these products.

The important ingredients for a healthy relationship between tropical biodiversity and the commercial world are

- An institution, such as INBio, that can serve as the broker to bring together the resources of Costa Rica Ltd. to facilitate joint commercial ventures with companies in the international community.
- International companies that are willing to enter into joint ventures in which they will have to be major contributing partners initially, in anticipation of modest but stable and socially acceptable future profits later on.
- A biodiversity that is sufficiently known and is well organized taxonomically to be studied, sampled, relocated, and reliably provided for use in the research and development programs of the joint venture; this taxonomic organization is a second major INBio function.
- A biodiversity whose ecology is understood well enough that ecological information becomes part of the phytochemical prospecting effort. This ecological understanding ranges from the bioassay test organisms in the laboratory to the multitude of wild consumers that, by the choices and patterns of their feeding, serve as guides to the presence of allelochemicals with substantial biological activity. Accumulating this ecological information is the domain of a multitude of institutions, INBio among them, working in Costa Rica's national park system as one giant biological research station.

In a socially friendly circumstance and a taxonomically literate country, traditional phytochemical screening, isolation, and testing are tedious but straightforward. While the process could be done in many different laboratories in developed countries, it would be cheaper and much more economically and socially acceptable to set it up in the country of origin of the chemicals. Costa Rica, for example, would have no problems with an industry of this sort—and the wild plants and insects would be growing just a few minutes away in its areas that are conserved for their biodiversity. Imagine what a boost it would be to the Costa Rican economy if just half of the development and production costs of new phytochemical-based pesticides or drugs by a major company were moved there. Costa Rica's entire government budget is only $1 billion per year, and a major pharmaceutical or pesticide company may spend half that on research and development per year.

The use of ecological information in phytochemical prospecting requires more explanation here. Thorough laboratory analyses and screening in laboratory bioassays eventually can locate the bulk of the interesting chemicals in a plant. However, while all animals are potential members of the coterie of guides to interesting wild phytochemicals, it is no secret to entomologists that feeding patterns by wild herbivorous insects, for example, can be used to shorten the search process. A seed, leaf, or a piece of wood that is not fed on by arthropods is an immediate candidate for a laboratory screen for very active phytochemicals. A plant part that is eaten by vertebrates and avoided by all insects is even more interesting. When T. Eisner speaks of phytochemical prospecting (Eisner 1990), he is one of the few who realizes just how many thousands of species of arthropods are members of the prospecting team. But it is necessary to be able to read, store, and retrieve these team members' reports.

There is already an enormous body of published research about the biology of tropical biodiversity. However, there is no central system anywhere that allows you, working in Costa Rica on the weevils that eat the seeds of the huge legume tree *Hymenaea courbaril*, to find out that someone has done almost the same study near a Brazilian university. Worse yet, neither researcher has any way to find out that a third person has done a study on the seed protein chemistry of those same seeds in yet another university in the undeveloped tropics. It is solely in the interest of Costa Rica to begin, at a minimum, the long and laborious task of coming to know what is already known about the species whose ranges extend into Costa

Rica. Phytochemical prospecting, tied to more than a century of exploration of thousands of species by natural-product chemists, is a prime rationale for this task.

In Closing

Costa Rica is, in a certain sense, one enormous biological research station that is just opening its gates. And putting tropical biodiversity to work for society is just now accelerating, despite the fact that society has been preparing for this race for thousands of years. We need participants. There are already conservationists and a few interested entrepreneurs. But there are tens of thousands of biologists—and specifically entomologists—who are still just watching. It's time to make the construction of the conservation process for tropical biodiversity a major goal for entomology, even if it means the partial exclusion of traditional entomological and national goals.

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