Sustainable Biodiversity Conservation

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by

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1. Sustainability
2. Biodiversity
3. Conservation

Advisor:

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Table of Contents

Table of Tables

Table of Figures

1. Abstract

The increase in awareness dealing with global sustainability has prompted reactions from INBio, a biodiversity company of Costa Rica. Through careful detailed study and documentation of ecosystems and organisms, INBio has been able to pioneer information gathering and dissemination. Our focus has concentrated on the discovery of spiders from the Oonopidae family. Our research and experience has provided us a valuable understanding of the sustainable conservation necessary to adequately provide for future generations.

2. Introduction

Human society is incredibly complex. As a whole, we are distinguished from all other known life by our profound ability to manipulate and control our environment. This allows us to influence everything around us. We generally try to improve our lives and the lives of our descendents. Frequently, we do this without thinking about the long term affects. More recently, we have started to consider the results of our actions. We are searching for more sustainable practices to lessen the consumerism that affects much of the world. Conservation is one major topic within the concept of sustainability; it is the application of sustainability principles to all kinds of life. Carrying out conservation can be quite complicated, and is further compounded by economic and political factors. We practice conservation based on what we know and understand. However, our understanding is often limited. In order to succeed in our conservationist effort, we must increase our understanding and apply our knowledge to the effective application of conservation practices.

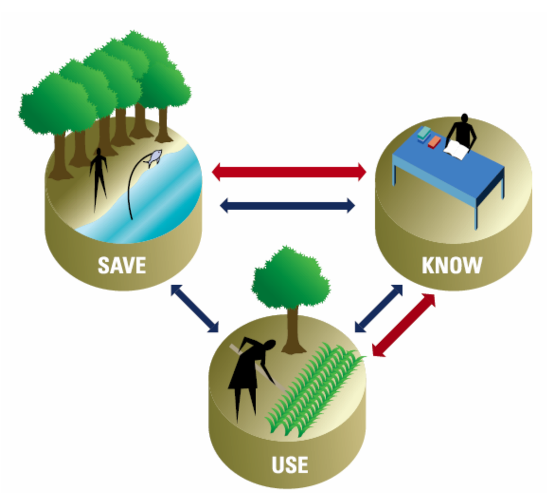
To better influence the environment around us, we need to supply what is lacking in our understanding by studying the environment as a whole. If we want to know how we can manipulate an ecosystem without inadvertently destroying something that we depend on, we must understand the complexities of how everything fits together. Ecosystems are incredibly complex; for any individual species to survive, several others must all play their parts. In addition, non-living factors must also be understood, such as weather, soil content, and water quality. A single complete ecosystem can only be understood to the level that each of the constituents is understood. Therefore, each life form must be first observed, and then studied, before we can understand the ecosystem as a whole.

One example of a human - ecosystem interaction failure is demonstrated in Rocky Mountain National Park. Wolves were eliminated in the late nineteenth century. Since the park is closed to hunting, the elk population formerly kept low by the wolves was allowed to grow substantially. Now, the elk have begun to permanently destroy the alpine tundra in some areas. The destruction of tundra takes away food sources from animals such as the marmot and pika, as well as allowing erosion and thus the destruction of habitat for all types of creatures such as insects. In such an extreme alpine environment it is not feasibly possible to import soil, forcing the National Park Service to consider reintroducing wolves or to hunt in such a way as to reduce the number of elk, or risk losing the entire ecosystem ("Colorado Wildlife").

The process of studying life in order to learn how to conserve and sustainably use the resources of Costa Rica and the world is discussed in this report. It is based on the process followed by the National Biodiversity Institute of Costa Rica (INBio), as observed by three foreign volunteers. INBio follows the Costa Rican model of conservation, which is summarized with the three words, "Save, Know, Use". In this report we consider each of these parts, especially focusing on the work of INBio itself, which is primarily the generation and dissemination of knowledge.

Figure 1: The role of INBio in the strategy for conserving biodiversity

Source: Jesús A. Ugalde and Randall García



3. Background

3.1. Costa Rica Facts

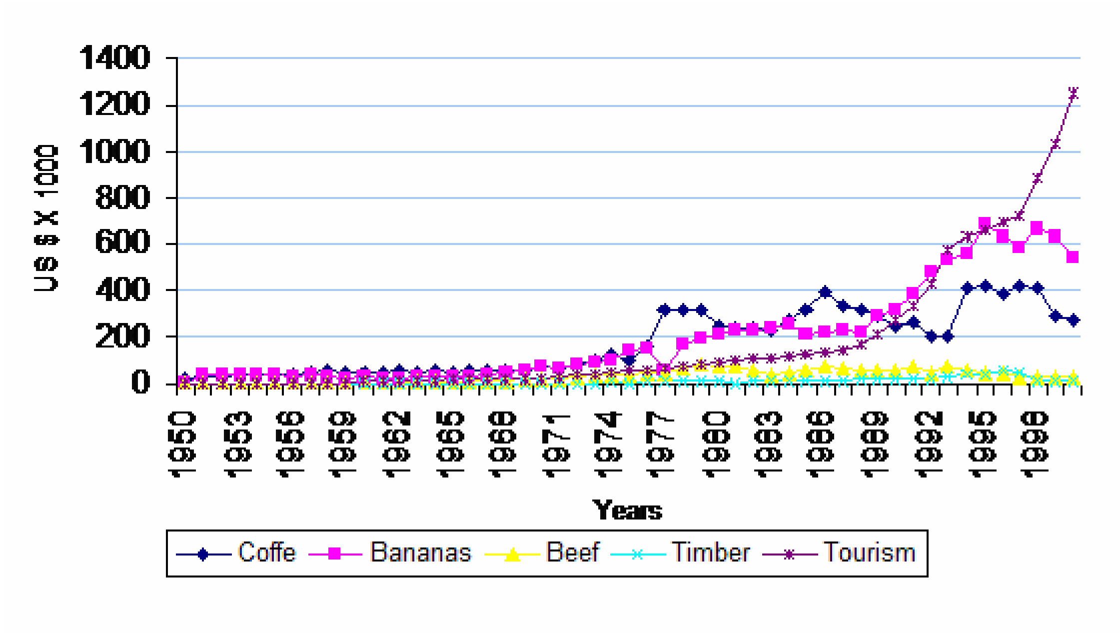
Costa Rica is biologically and geographically a very diverse country, comprising approximately 19,700 square miles, an area roughly the size of West Virginia or twice the size of Massachusetts (The World FactBook). The elevation ranges from sea level to 12,530 feet at the top of the highest mountain, Cerro Chirripó. A central mountain range divides the Atlantic from the Pacific coasts, which range from 75 to 165 miles apart (Costa Rica). Costa Rica is also about 10 degrees north of the equator which means it is very hot much of the year with average temperatures in the central valley ranging from 57 to 72 Fahrenheit and near the ocean coast 72 to 82 Fahrenheit (Costa Rica Travel). This excludes the temperature extremes both on the top of the mountains and near the ocean at midday which indicates the potential for more extreme temperatures.

One of the most unique things about Costa Rica is the density of species. It is estimated by INBio that 4% of the species of the world are in Costa Rica yet the country only occupies .03% of the world's land area. This makes it one of the 20 countries in the world with the greatest biodiversity (Biodiversity in Costa Rica). Throughout the past, ice-ages and climate changes have contributed to the spread of species throughout North America and the world. However, in tropical areas such as Costa Rica, climate changes have not been as dramatic. As a result, some species have very limited ranges, such as one particular mountain (Borken). As the temperature changed over time the species were able to go up and down the mountain while never moving very far in any of the cardinal directions. Tropical climates also support the flourishing of insects. Of the country's more than 500,000 species more than 300,000 of them are insects (Biodiversity in Costa Rica). Finally, the abundance of mountains divides the land into a variety of climates, which each have developed distinct ecosystems with many species that reside in only one single location (Wood). While species with small ranges are common throughout the world they are important to study because a small action by a small group of people could have devastating consequences for that species.

There are a number of issues that make Costa Rica very unique with regard to biodiversity. There are countries with much more biodiversity such as Brazil (World Conservation). However, they are much larger, so species are more spread out. Often they are also in nearly inaccessible areas such as remote tributaries of the Amazon. Additionally *Ticos*, as Costa Ricans call themselves, are quite proud of their country's flora and fauna. The government is particularly favorable toward the promotion of conservation and sustainability. They have set aside an astounding 25 percent of their country as national parks (Costa Rica Travel). The large percentage of preserved land invokes interest by a number of individuals and contributes to the study of Costa Rica's natural resources (Borken). Since becoming the first country in the world to abolish their military in 1948, they have enjoyed political stability that is rare among Central American countries (Costa Rica History). These combine to make Costa Rica an ideal base from which to study biodiversity. Ranking 15th on the biodiversity scale, Costa Rica is a very small country that is easily accessible to modern science (World Conservation). Costa Rica is also developed enough to support national scientific research another rare trait in the tropical mega diverse countries.

The United States by contrast has only 3.5 percent of its land designated as National Park Service land (Land Resources). Even though we have approximately 340,000 square kilometers of national park land compared to Costa Rica’s 13,000, we still fall very short percentage wise. Costa Rica also has a much larger percentage of their income based on tourism, especially ecotourism, than more developed countries such as the United States. In fact, Costa Rica's second largest income, exceeded only by electronic components, is tourism which accounts for more than double their income from bananas and quadruple their income from coffee ("Toward a Sustainable INBio" 8). In the United States on the other hand only about 4% of our gross domestic product is from tourism ranking behind many other industries (U.S. Department of State). These numbers show that Costa Rica has a valuable resource and they are very dependent on the tourists from foreign countries as a source of income.

Figure 2: Costa Rican Exports



Source: "Toward a Sustainable INBio"

3.2. Ministry of the Environment and Energy – MINAE

MINAE is the government agency created to guarantee the constitutional rights of Costa Rica's environment (MINAE). MINAE is divided into two parts: the Department of Energy, and SINAC, the National System of Conservation Areas. SINAC works closely with INBio in many areas, and runs Costa Rica's system of National Parks in conjunction with other governmental groups and biodiversity companies similar to INBio. SINAC was created in 1988 so that there would be a government department strictly dealing with the national parks and biodiversity ("Informacion General"). They regulate the fees that a park takes in and the various rules and regulations in place within the parks. SINAC is responsible for the 20 national parks, eight biological reserves and the national monument ("Costa Rica National Parks"). Something that is interesting about SINAC is its reliance on donations as a government branch. The Netherlands investigated the sustainability of SINAC from 1998 to 2002, contributing the majority of 4.2 million dollars needed for that project ("Toward a Sustainable INBio" 30). They also donated toward several other projects during that time.

There is also a problem with illegal poaching and wood harvesting in Costa Rica, because there are a number of species, such as the cocobolo tree, that are native to Costa Rica and only grow in a relatively small location. SINAC exists in part to curtail the illegal activities within Costa Rica and especially in the national parks. It is estimated that 25 to 35 percent of wood products on the market have been illegally harvested, often from national parks ("Informacion General"). These astounding statistics along with others for animal poaching allow SINAC to hire more rangers and staff members to patrol the parks to maintain a safe atmosphere.

MINAE and SINAC are also quite vital in the role they play as environmental lobbyists. Costa Rica in general takes ecotourism quite seriously and is more environmentally conscious than many other countries. While 25 percent of the country is designated national park, 75 percent of the country is still not preserved to the extent the national parks are. SINAC must continually lobby in the Costa Rican Congress for the protection of the vital natural resources within the country and its surrounding waters ("Informacion General"). With successful political representation they are able to insure that none of the national parks lose necessary funding or legal protection.

3.3. National Institute for Biodiversity – INBio

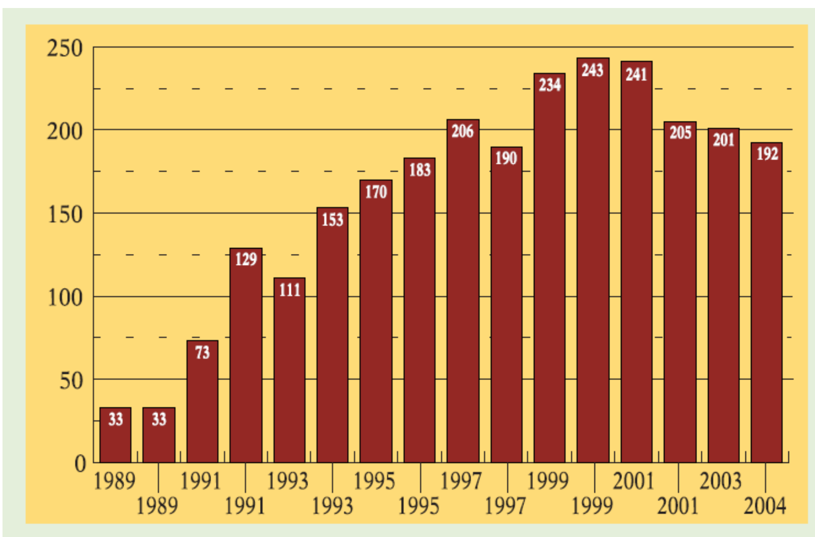
INBio exists because of an executive directive given in 1989 (Garcia). An executive directive is similar to creating a law in the U.S. The legislature writes the directive, and the executive branch signs it to make it into law ("Constitution"). This executive directive established a planning commission for a national institute of biodiversity. Due to various political and economic factors, the government was unable to act on the commission's recommendation. When told this, the commission members took it upon themselves to create a private non-profit institute instead ("Toward a Sustainable INBio" 8). The idea received federal support, and has become the *Instituto Nacional de Biodiversidad* ("What is INBio?").

The mission of INBio is, "To promote a greater awareness of the value of biodiversity as a means to ensure its conservation and improve the quality of life of human beings" ("What is INBio?"). INBio pursues this mission according to the following vision. "INBio is a scientific and technological organization of recognized excellence and leadership that generates information and promotes initiatives for the conservation and sustainable use of biodiversity, incorporating these into the endeavors of society" ("What is INBio?").

INBio is divided into twelve departments. Four specialize in the study of particular life forms: Arthropods, Fungi, Plants, and Vertebrates. Three help to develop tools and resources for such study: Communications, Informatics Development, and Geographic Information System. Four are involved with education: Training, Ecotourism, *INBioparque*, and INBio Editorial. The final department, Bioprospecting, seeks to develop products that will benefit society (What is INBio?).

One problem that has plagued INBio in the past is funding. As of 2002, funding for INBio came from a number of different sources: 8% from the Patrimonial Trust Fund, 38% from INBio's income generating processes such as *INBioparque* and Bioprospecting, and 54% from soft funds such as donations. Nearly all of INBio's soft funds came from the Netherlands and the GEF, the World Bank's Global Environmental Facility; however, those sources of funding ended in 2005 and 2004 respectively (Van de Putte 7). Throughout that time, INBio averaged 240 employees. Since the cut in funding, the number of staff has dropped to about 175 people. This is lower than what leadership considers optimal: from 200 to 220 staff members ("Toward a Sustainable INBio." 12). These budget cuts and lay-offs have resulted in a large portion of the work being done by retired foreign volunteer specialists. The result was the closure of various programs, such as the marine department, and lowering the number of staff in others (Lewis).

Figure 3: INBio's Staff



Source: Bert van de Putte and Randall García

Table 1: Distribution of costs 1998 – 2001 (1000 US $)

Component	**1998**	**1999**	**2000**	**2001**
Administration	600	931	1,005	1,209
Social Outreach	402	1,228	590	839
Information Management	360	475	526	495
Inventory	1,174	1,651	1,851	1,677

INBioparque	0	0	1,150	1,444
Special Programmes	195	82	95	167
Bioprospection	753	570	842	839
Publishing	0	0	166	208
Conservation	558	1,170	990	946
Total	4,042	6,107	7,215	7,824

Source: “Toward a Sustainable INBio”

Table 2: Income of INBio by source from 1998 – 2001 (1000 US $)

Source of income	**1998**	**1999**	**2000**	**2001**
Products and services	751	925	1,426	2,311
Endowment fund	1,277	499	377	273
Soft funds	2,698	4,685	5,704	4,245
Total	4,726	6,109	7,507	6,829

Source: “Toward a Sustainable INBio”

As a result of the history of Costa Rica and all the progress made in the past years as far as biology, INBio is on the cutting edge of discovering and exploring the world that we live in ("What is INBio"). INBio has also participated in a large number of new species descriptions. As of 2002 over 1,500 previously unknown species have been described due to the work of INBio ("Toward a Sustainable INBio" 26). It is also interesting to note that the large collection of specimens that INBio has collected cost 7.6 million dollars to index taxonomically and maintain between 1998 and 2002 ("Toward a Sustainable INBio" 26). While the costs of such a collection are quite large, the information contained in the Atta computer database are valuable tools researchers use to complement their own field work and study of ecosystems.

3.4. Cooperation between INBio and MINAE

Between INBio and SINAC, there was a program from 1997 to 1999 known as ENB, National Strategy for Conservation and Sustainable Use of Biodiversity. ENB was an effort involving about 1000 people from public and private sectors to develop conservation and sustainable use practices in areas ranging from agriculture to the average home (Gámez 14). They worked with various professionals to define current problems and develop realistic solutions. It is imperative that Costa Rica learns how to use its resources sustainably for a number of reasons. The largest amount of foreign income that Costa Rica receives is due to ecotourism; it would be unwise for them to exploit biodiversity to its destruction (Van Tassel). This is a major problem created by tourist amenities like large hotels and elaborate outdoor recreation facilities. If this trend continues, Costa Rica will be left with very little biodiversity, tourists will stop coming, leading to economic difficulties (López).

INBio fits into the picture primarily by studying the various ecosystems within Costa Rica. This information can then be charted on maps using the *ECOMAPAS* program that began in 1998 to identify where species throughout Costa Rica reside (Gámez 10). This is one of the reasons INBio is so unique; it has detailed information about all of its specimens based on exact location and altitude. Many biological collections throughout the world are old and do not include information more detailed than the province or even continent in some cases. INBio's attention to detail in its collection allows for more productive study (Lewis). In short, INBio researchers learn everything they can about the various species, and then teach others how to use this knowledge to develop sustainable practices. The goal is to develop a stable interaction with each ecosystem, so that it is not degraded by human activity.

The *ECOMAPAS* program has resulted in the intense mapping of over 44% of Costa Rica’s land surface ("Toward a Sustainable INBio." 36). This large volume of information has allowed SINAC to strengthen their institution and provide for a more sustainable organization. With funding from the Netherlands as well as courses and workshops dealing with conservation biology, SINAC has been able to expand. . In the years 1998 to 2002, INBio invested around 220,000 dollars out of 630,000 dollars in profits from the bio-prospecting department into SINAC. Since INBio began donating money to SINAC, it has been able to build new biological stations in five different parts of Costa Rica ("Toward a Sustainable INBio" 28). This level of dependence and cooperation between a non-profit company and the government has allowed the national park system to grow and develop into a high quality educational and recreational product. This cooperation contributes to the attraction of Costa Rica as an ecotourism destination.

3.5. Ecosystems

An ecosystem is the context in which all study of life is conducted. The word "ecosystem" itself is a concatenation of the phrase, "ecological system". It consists of all life and how living organisms interact with one another and their abiotic environment. As a result, ecosystems are divided and classified according to geographical and physical characteristics as well as according to the types of life forms that live therein ("Ecosystem"). Ecosystems are highly dependent on all their components. Tying everything together in complicated ways allows even small changes to be felt throughout the whole ecosystem. If one species becomes extinct, than all its predators lose their source of food, and all of its food sources can grow uncontrolled, thus changing the ecosystem. Changes in the environment have the possibility of adversly affecting the ecosystem permanently. Sometimes this happens due to natural disasters, like earthquakes, volcanic eruptions, large storms, or climate change. However, in recent history the biggest impact by far has been due to humanity (Greenfacts).

Humans impact various ecosystems in diverse manners. We take advantage of the resources that an ecosystem provides, by logging the wood, farming the land, hunting and fishing. We build dams, highways, and cities that control and intrude on the preexisting ecosystem. In these and many other ways, we have a significant effect on ecosystems around the world (Greenfacts). Similarly, humans are dependant on and affected by the ecosystem, and are therefore affected by any changes therein. One clear example of this is when we harvest a natural resource, lumber for example, until the supply is completely exhausted. We are then faced with the fact that there are no more trees in the area, and we must adapt to the change. We are also affected by changes in the climate, which are often due to the changes we made to the landscape and atmospheric composition (Greenfacts). We have made permanent changes to the world's ecosystems and are beginning to study the effect we are having.

3.6. Ecosystems of Costa Rica

There are 12 ecosystem zones in Costa Rica; however, the most prominent are tropical dry forests, tropical rain forests, and mangrove swamps. Simple zones, like mangrove swamps, coexist with one of the most complex systems on earth, the rainforest. Costa Rica’s varying elevations and geography encourage multiple ecosystems to flourish. For example, in the south of the country, the lowland rainforests closely resemble South American jungles. The tropical rainforests inhabit the eastern part of the country and the Osa Peninsula, while dry evergreen forests cling to lower elevations in the central Pacific and dry deciduous forests in the north. At high altitudes, the landscape suggests the flora of high elevations in the Andes. In addition to these inland areas, Costa Rica also possesses an abundance of underwater ecosystems including streams and costal areas (Baker).

The wide variety of ecosystems supports a huge variety of life. Costa Rica lays claim to roughly 800 species of fern alone, more than all of North America and Mexico combined ("Flora"). Plant life is breathtakingly colorful, coming in all the shades of the rainbow. The most well known type of flora is the orchid, of which 1400 species have been identified within Costa Rica’s shores. The orchid is the national flower of Costa Rica, and is the most prolific of all flowering plants, as well as the most diverse. Orchids can be found with flowers smaller than a millimeter and larger than half a meter. Some flower for weeks, while others flower for a single day. Orchids can be found in almost every part of the country, from sea level to the highest heights. Many orchids are considered epiphytic. Epiphytes are plants that grow high in the treetops or climb up huge trunks. They can often be found on tree branches, sometimes weighing the branch down so much that it breaks and crashes to the forest floor. Bromeliads are a type of epiphyte that collect large quantities of rainwater and decaying organic material and then siphon nutrients from the mixture. They are often the homes of small aquatic species like some frogs. There are more than 2000 species of bromeliads in the forests of Costa Rica (Baker). Epiphytes are vital to the rainforest ecosystem because they provide food, shelter and water to many species.

Most of the biodiversity in Costa Rica is found in the tropical rainforests. These ecosystems are so important that the entire following section is devoted to them. While rainforests hold a large percentage of the flora and fauna of Costa Rica, there are also other zones less populated. These include the endangered tropical dry forests of the mountainous regions near Guanacaste. Dry forests have been reduced to 520 square kilometers of scattered territory, a mere two percent of their former land. The dry forests have only two levels: the canopy and the understory (Baker). Canopy trees are rarely taller than 15 meters and tend to have short, stout trunks ("Flora"). The understory consists of smaller trees with a layer of shrubbery containing spines and thorns. The colors of the dry forests, come out during the dry season, when drought is at its worst, blossoming into purples, pinks, yellows, reds, and oranges ("Flora"). Farming and ranching is threatening the existence of these patches of forest with fires set to enrich soil for planting. These fires allow opportunistic flora like African *jaragua* to take over land, eventually turning former forest into savanna (Baker). The spread of agriculture has coincided with the loss of forest land throughout the world and most devastatingly through the tropical rainforests.

One of the least noticed of Costa Rica’s ecosystems, yet one of the most important, is the Mangrove estuaries that proliferate along the coastlines of Costa Rica. Costa Rica is home to five species of mangroves, all of which slowly capture the sea and form land. Mangroves thrive in the mouths of streams and rivers, trapping silt and nutrient-rich mud with their aerial roots. They are homes to hundreds of developing marine life forms, essentially becoming nurseries for important species of the sea (Baker). Along with supporting oysters, sponges, stingrays, and baby fish of all kinds, mangroves provide homes to hundreds of types of water birds like cormorants, frigate birds, pelicans, herons, and egrets. Mangroves are also very sturdy species. The seed sprouts and grows up to 30 centimeters before falling from the parent tree. Upon hitting mud or soil, roots are put down immediately, though the seed can survive for up to a year on the tides before laying down roots. Once rooted, the seedling grows almost 60 centimeters in the first year, and in ten years, a new colony of mangrove trees has been born. As silt increases, mangroves slowly strand themselves and die, thus reclaiming a little of what the sea steals (Baker).

Costa Rica is positioned with a large number of ecosystems and one of the world's most untouched rainforests making it ideal as the world's national biodiversity park. There are few places on earth where oceans, mountains and jungles are so close together. Moreover, the combination of ecosystems, cultural knowledge and political protection is rare as well. INBio could not exist in most of the United States because we just do not have the biodiversity density of the ecosystems of Costa Rica.

3.7. The Rainforest

Of all the ecosystems found in Costa Rica, the tropical rainforests are simultaneously the most famous and the least known. That is to say, they are known to be extremely important, precisely because so much biodiversity, practically unknown to science, is found within. Rainforests generally have five layers. These layers are the floor, the shrub layer, the under study, the canopy, and the overstudy. The canopy is the dense layer of leaves and branches 100 to 130 feet above the floor of the rainforest. Scattered emergent trees, over 130 feet high, form the overstudy. The understudy is the level of widely spaced leaves and branches below the canopy, and the shrub layer is the lowest part of the understudy, at 5 to 20 feet above the forest floor (Butler, "Ecology"). Though seemingly dense, the branches forming the canopy layer do not touch. Scientists are still unsure why this occurs, but current theories believe the practice is for protection against disease and predators like tree-eating caterpillars. Because of the need to traverse these gaps, larger canopy species have developed unique adaptations to assist in climbing, leaping, gliding, and flying (Butler, "Canopy-Introduction").

One of the reasons the canopy is such a vital place to live is because of plants called epiphytes. Epiphytes are plants that grow on another plant without harming their host. For example, orchids are brilliantly colored epiphytes that grow on trees in the rainforest. Epiphytes are important to canopy life because they provide microenvironments in which many insects and organisms thrive. These environments are partially created by the epiphytic plant itself and partially due to the abundance of detritus and leaf litter that collects in the branch cavities. Epiphytes have adapted many ways to collect nutrients and spread their seeds. Some create bucket-like shapes that hold water and decaying organic matter. These plants then collect nutrients from the stored water while many tiny creatures make that water their home. Others use the art of imitation to attract insects and pollinators into collecting pollen at their flowers. Still others use scents attractive to certain species that force those insects to collect pollen. Some use a wide-root system to store and hold water to be used later, while others use thick hairs similar to cacti spines to close stomata and prevent loss of water. Many epiphytes have symbiotic relationships with their inhabitants, gaining nutrients for a place to live. Epiphytes are widely distributed throughout the rainforest due to their overabundance of seeds. Epiphytic seeds tend to be very small and are often dispersed by the wind, ensuring that some will land in a suitable spot to grow (Butler, "Canopy - Epiphytes").

The canopy also serves as a protective layer to the understudy, shrub layer, and ground floor. The density of leaf cover prevents most sunlight from hitting the forest floor directly, thus shielding the floor from radiation, most winds, and heavy rainfall. The canopy also traps moisture between it and the floor, forcing humidity to remain relatively constant underneath the canopy. This shield effect produces an interesting dynamic on the forest floor (Butler, "Canopy-Introduction").

The forest floor is in constant shade due to the canopy. The lack of direct sunlight keeps the forest floor relatively clear of choking vegetation. Large tree trunks, hanging vines, saplings and seedlings, and adapted ground plants cover the forest floor instead (Butler, "Forest Floor". Underneath these plants lie a thick layer of rotting leaves and detritus from the canopy overhead. Every so often, where a large tree has fallen or there is a break in the canopy, a shaft of sunlight will break through to the forest floor. At these points, hundreds of plants fight to gain an advantage, producing the dense ground growth familiar to most people.

Leaf litter on the forest floor is a major habitat of spiders of the Oonopidae family of spiders. It is composed of leaves in various stages of decay, and is home to thousands of species of fungi, protists, parasites, arthropods, lichens, and bacteria. The decomposition process is completed by fungi, bacteria, protozoa, and some animal species, releasing important nutrients back into the ecosystem. These species are, in turn, preyed upon by other species, including Oonopidae spiders. These predator species provide prey in turn for larger species, thus transferring nutrients from the leaves back through the food web. Nutrients are also broken down into usable forms by certain plants growing on the forest floor, thus allowing some of those nutrients to be recycled back into the growth of other plants (Gray). Many beetle larvae aid in the decomposition process by consuming floor litter and then defecating dirt (Hernandez). The larvae then are also available as prey for more species thus fulfilling their role in the ecosystem.

Tropical rainforests are extremely moist and hot, humidity being 90% at ground level and 60% to 95% in treetops due to breezes and openings in the canopy. Rainforests support a vast amount of different species due to the heat, humidity, and fast nutrient turnover. As an example of just how quickly decay happens in rainforests, a leaf of a North American oak may take a year to decompose, while a leaf in a rainforest may take no longer than a single month. However, the ground remains relatively clear of growing plant life due to only 10% of total sunlight penetrating through the forest canopy to the forest floor. One interesting adaptation to the sparse sunlight is the “walking palm” which actually follows the sunlight on its stilt-like roots. Other adaptations include purple shading on the bottom of leaves to reflect sunlight back into leaves, and avoiding the shadows cast by other leaves (Baker).

Rainforests are often known for their power to renew the atmosphere by production of oxygen. This power comes from the billions of leaves that are performing photosynthesis every day. Photosynthesis converts sunlight to energy through use of carbon dioxide and transfer of electrons. Oxygen is actually a waste product of photosynthesis that the plant cannot use and thus gives off into the atmosphere. Rainforests have a huge output of oxygen because they are situated near the equator, where the sun hits most directly at a near-90 degree angle allowing the plants to use photosynthesis year-round. The high rate of photosynthesis allows for a high output of reproductive necessities such as flowers, fruits and seeds. The sheer number of plants forces the maintenance of a very diverse variety of species of plants to protect any single species from over-competition. In turn, the diversity of plant life contributes to the diverse species that specialize in consumption or use of certain plants. It is estimated that 70 to 90 percent of all rainforest species live in the trees (Butler, "Canopy-Introduction").

Rainforests are unique in that species rarely congregate into groups, that is one specimen of a tree may be over half a mile from the next specimen of the same tree. Due to frequent rain, trees tend to have shallower roots, instead growing buttresses to support their immensely tall trunks. Trees in the rainforest are generally well over 35 meters tall with huge, flat-topped crowns. A few giants poke through the canopies growing over 70 meters in height (Baker). The immense variety of trees allow an equally immense variety of tree eating species to be able to survive in a small area.

Rainforests are so complex that a good count of the species contained therein has yet to be reached. Hundreds of species of birds flit among the treetops, shrieking as they move. Rodents run among the branches, catching insects and drinking nectar. Multitudes of monkeys, sloths, and other mammals also live high in the branches, searching for leaves and fruit. There are also hunters, including giant cats, smaller snakes that feast on frogs, lizards and birds, and eagles that eat monkeys. Bats, beetles, moths, butterflies, and a host of flying bugs each fulfill a niche as predators, prey and even soil creation (Baker).

3.8. Oonopidae Taxonomy

Taxonomy is the classification of life into various groups. There are seven major levels of classification: kingdom, phylum, class, order, family, genus, species. INBio's Atta database consists of 22 total levels, counting these seven as well as sub-levels, super-levels, and others between. These are often introduced to give better distinction to a group of organisms. For example, dogs are all the same species but there are many different sub-species known as breeds. Similar strategies are applied to all of the other taxonomic ranks as well.

Kingdom: Animalia

There are five universally recognized kingdoms: Monera, Protista, Fungi, Plantae and Animalia. Each kingdom represents a more advanced biological function. Monera is the simplest. Known commonly as bacteria, they are prokaryotic, which means they are so simple that their cells do not have a nucleus and the DNA material simply floats within the cell. The next step up is the Protista kingdom, consisting of single-celled organisms as well as multicellular organisms. Protists have more complicated cell structure including a nucleus which classifies them eukaryotic. Fungi is the kingdom containing eukaryotic organisms such as mushrooms that are capable of externally digesting their food and absorbing the nutrients, making them heterotrophs. Plantae is the kingdom with multicellular eukaryotic organisms. Most plants conduct photosynthesis and are able to produce their own food which classifies them as autotrophs. They contain complex cell structure and often complex tissue structure with diverse functions such as roots, xylem and phloem, bark and leaves. The final kingdom is Animalia consisting of eukaryotic heterotrophs. All insects and mammals fit into this kingdom. Animals are also capable of moving, and it is necessary for them to move to look for their food (Westbroek).

Phylum: Arthropoda

There are 21 different phyla in the Animalia kingdom. They vary from different worms such as flatworms and ring worms to other creatures such as sponges and jelly fish. Humans are in the Chordata phylum with the other vertebrates. The focus of our study has been with the phylum Arthropoda. Arthropods are generally characterized by head, thorax and abdomen and at least three pairs of jointed legs as well as an exoskeleton, which is molted at intervals (Armstrong). The Arachnida class is further distinguished within the subphylum Chelicerata, which separates them from the Insect class because they have 4 pairs of legs, one pair of pedipalps, and one pair of chelicerae (Myers). In spiders, the chelicerae function roughly as hands to help in grasping and eating, while the pedipalps serve a variety of functions ("Pedipalps."). Arthropods is one of the departments of INBio and has its own building with ongoing projects dealing with creatures like flies, spiders, beetles, and moths. This phylum holds some of the greatest chances for species exploration since many of its creatures are very small and have not been thoroughly studied. The lack of previous exploration is one of the reasons INBio is so interested in this biological sect.

Class: Arachnida

The next taxonomic description is class. We are most interested in the Arachnida class which contains over 60,000 described species. Most of the species of this class are spiders. The rest consist of mites, ticks, and scorpions. Arachnids are distinguished from other Chelicerata in that they have two distinct body separations, rather than three. These creatures are characterized by a prosoma, the front region, often covered with a shield, as well as an opithosoma, the tail end, which in the case of spiders are called spinnerets (Myers "Arachnida").

Order: Aranae

Every class is then divided into various orders. We are interested specifically in the Araneae order of the Arachnida class. These are known as spiders (Platnik). These organisms consist of all the classic spider traits generally including: eight legs, two body parts, spinnerets, and pedipalps. Spiders are further classified by the location and number of their spinnerets, and the structure of their genitalia. Finally, spiders are uniquely identified by the fact that all spiders produce silk, which is used for webs, transportation, reproduction, and various other purposes (Petrunkevitch). As of December 31, 2006 there were a total of three sub orders, 108 families, 3677 genera and 39,725 species of spiders (Platnik). This exponential growth is representative of all life. These numbers show a sampling of just how many species there are and how much diversity there is that we lump together under one term.

Family: Oonopidae

This family is characterized by tiny, almost mite-like spiders generally one to three millimeters in length. They are found throughout the world (Chickering 77). One of the reasons these spiders are important is their mega diversity as well as their small ranges. The individuality of an ecosystem can be determined from the species it contains that no other ecosystem on earth has. At present there are 459 species and 67 genera of the family Oonopidae. Professional estimates suggest that this is about 20% of the species of this family that exist ("Oonopidae"). Their microscopic size is one of the reasons that so little information is known about this family. A collector can easily miss these spiders while collecting samples.

Many of the Oonopidae family of spiders that are recorded to date are in tropical or subtropical regions of the world, primarily rainforests. However, they are not limited to such warm climates and are found on all continents except Antarctica (Chickering 77). Many of the tropical samplings done in the past have concentrated on ground litter surveys and have rarely studied the forest canopies, where it is hypothesized that many more Oonopidae species live. It is also interesting to note that Oonopidae generally have six eyes, although ocassionally having only two or zero, contrary to the normal eight that most spiders have.

Genus

There is also the genus level which consists of very closely related organisms. Usually there is one world expert on a specific genus (Lewis). One example of a commonly known genus is Equus, which contains both the horse and donkey (Moehlman). They are in the same genus and are close enough genetically to reproduce together. However, they are clearly different species, since the mule produced is sterile. Often with microscopic insects many scholars are only able to identify a given specimen down to the genus level because the species appear so similar. For the comprehensive Central American fly manual being created by scientists throughout the world, the description is only specific to the genus level. Consult the Methodology, To Know section and Description of New Species sub section for further details. Even the genus level of identification often requires a microscope and such specific observations as the number of hairs on a specimen (Wood).

Species

Finally we come to the species level, which consists of ogranisms that are able to reproduce productive offspring. In larger organisms, there are often specialists dealing with one species such as the grizzly bear or elephant or even humans. Identifying down to the species level is very difficult in insects because of their often microscopic size and extremely similar appearances. They often look so similar that is it is nearly impossible to tell them apart without an extremely thorough investigation (Wood). This is also the taxonomic level that is most often discovered as it is the most diverse.

4. Methodology

The conservation of biodiversity is a long process, involving many steps that each take years before any significant progress is made. The Costa Rican model for conservation is summarized by the phrase, "Save - Know - Use". These three are done simultaneously, each one making the other two more effective. These are commonly depicted as a triangle, each aspect at one corner with arrows pointing toward the other two. Only when all three aspects are functioning can conservation be accomplished in a sustainable manner. For the purposes of this paper, we will first briefly consider the process of "saving" biodiversity, which is primarily done by the government and land owners. Then we will go into much greater depth on what INBio specifically does to advance the causes of knowing and using biodiversity.

4.1. Save

There are essentially three types of land management practices: preservation, conservation and exploitation. Preservation is the theory that land is better managed without any human involvement. For example, fires are allowed to burn and no roads would be built. Conservation is the practice of sustainably using the land so that it will be available for future generations. While some of the land may be used, other parts may not be used. A perfect example would be the national forests of the United States. Ranchers are allowed to use the land for grazing and there are roads and trails available for recreation. However, fires are generally allowed to burn themselves out unless they threaten personal property, and it is illegal to build new permanent structures. Exploitation is the destruction of an ecosystem. Clear cutting forests, open pit mining, landfills, and cities fall into this category. Choosing a general land management practice is based on factors such as economics, politics, and the desire of the owner. With such individuality and a large ecotourism market, Costa Rica has chosen in large part conservation and also preservation as a means of saving their land.

Conservation begins when some entity decides to set aside a certain area of land, purposely limiting human influence. This can be done many ways, but is usually done by the government declaring a national park. In fact, Costa Rica has already set aside over twenty-five percent of their land area as national parks (Costa Rica Travel). However, these parks are not always left completely free of human influence. They are managed by SINAC, the environmental division of the governmental agency MINAE. See sections 1.2 and 1.4 of the background for more details about SINAC and MINAE. Most of the national parks build trails through a certain portion of the land and allow tourists to enter and observe, for a fee. The money is then used to further the causes of conservation as well as benefit the country as a whole. This is known as ecotourism.

There are many complicated questions regarding the creation and management of national parks. For example, how much land is necessary? Is it better to have one big park, or two smaller ones? How far apart should they be? At first glance, many of these questions might not seem very complicated. However, with a little further study, the apparent complexity of the situation rapidly increases. One example was given in a lecture by Randall Garcia, one of the directors of INBio. It is commonly known that when a species habitually mates with close relatives such as siblings or cousins, genetic defects are propagated and multiplied. Historically, this explains the eccentricities of many royal families that insisted on marrying only royal blood. This needs to be considered along with the fact that many predators, such as jaguars and pumas, cannot live within close proximity of one another. For example, each female jaguar requires 30 square kilometers, and each male requires 90 square kilometers. If an individual park is a few hundred square kilometers, than there is only enough room for a few jaguars to live. If there aren't enough specimens with a direct natural connection to one another, after a few generations they will be required to mate with their siblings and cousins. Thus, poorly planned and managed conservation land indirectly causes genetic degradation.

Another example is that different kinds of birds require specific plants found only at certain altitudes in particular seasons. These seasonal residences must be within a certain range; otherwise the birds will not be able to travel between them. Many other examples could be given that relate the management of national parks and the "saving" aspect of conservation with the necessity to study the populations being saved. Unless we thoroughly understand the requirements of the organisms enclosed, our attempts at conservation will be severely handicapped. They will undoubtedly succeed occasionally, but only by chance. Therefore, while the first step toward conservation is to save, it alone is not enough. It must be constantly complimented and perfected by the other two points of the triangle.

4.2. Know

To know is the second step in the Costa Rican model for conservation. INBio's primary role is within this step: the generation and dissemination of knowledge related to conservation. It begins with the collection of specimens from various ecosystems. Different types of specimens are collected in different manners, but usually hundreds of specimens are collected at a time. These specimens are then sorted, preserved, and added to the collection. Then they are available for use by taxonomists in the study and classification of specific families, genera, and species. Quite frequently, new species are identified, named, and described at this part of the process. Collecting and identifying species is only the very beginning, merely providing an outline of what remains to be studied. A taxonomic description of a species tells us only what it looks like, but tells us nothing of its life: how long it lives, what phases it goes through, what it eats, what preys on it, and how it fits into its ecosystem. Only with such detailed information can we begin to piece together how the ecosystem works as a whole.

INBio itself works on many pieces of this process, specifically within Costa Rica. According to Monty Wood, an experienced entomologist who has traveled the world studying flies, INBio's collection of arthropods exceeds any collection to be found around the world. This is significant in the study of biodiversity, since the vast majority of the world's species are insects, which is only one class within the arthropod phylum (Hickman, 544-545). INBio also has departments studying botany and fungi, each with their own collections. In addition to their taxonomic contributions, INBio has several ongoing projects studying specific families and genera in greater detail. Finally, INBio is committed to the application of this knowledge. They built *INBioparque* to display and teach about the various ecosystems they are studying, and frequently sponsor many educational programs. They also work closely with SINAC - MINAE.

4.2.1. Collection Methods for Arthropods

The first step in the process is to take samples of plants and animals from all over the country. This is done by carefully trained parataxonomists. Parataxonomists are specialists trained in the collection, preparation, and preliminary identification of specimens ("Arthropods"). The difference between a parataxonomist and a taxonomist is similar to that between a doctor and a paramedic (Lewis). Arthropods specifically are collected through several methods of traps, including manual, pitfall traps, and Berlese Funnels. The material from each of these traps is then preserved and added to INBio's collection. It is very important that every specimen is properly labeled, so that when it is eventually studied, all necessary information is known. A proper label includes the location, date, method, and the name of the collector. Without this information, the specimen provides no new information and is therefore lost to science.

Each trap requires the use of a killing jar or suitable equivalent. A killing jar is a jar containing an agent that induces death in the arthropod. The agent used is often dependent on the kind of insect or arthropod intended for collection. Some examples of liquid killing agents are ethyl acetate, ether, chloroform, and ammonia. Ethyl acetate is widely preferred as a liquid killing agent because specimens will not harden as long as they are submerged. Solid killing agents used include ammonium carbonate, potassium cyanide, sodium cyanide, and calcium cyanide. The cyanides are extremely poisonous to humans, and are generally not preferred because specimens harden very fast when killed with a cyanide ("Collecting and Preserving").

The following traps are only the most common methods used for the collection of Arthropods. There are countless other methods, many of which are only used in very specific situations. Parataxonomists are constantly learning new methods, as they confer with the experts on specific families and genera on how best to collect their desired samples (Lewis). See Appendix II for tool and trap diagrams and pictures.

Manual

Manual methods of trapping require continuous effort on the part of the collector, and are often known as active methods. Manual methods are excellent for collecting many arthropods closely associated with particular microhabitats, such as a bush or individual tree. There are several different types of manual methods. Sweeping requires the use of an aerial net and consists of sweeping the net through vegetation; it works well for insects that are poor fliers and do not fall off when disturbed or sit high on vegetation. Litter sifting consists of taking a designated area usually one meter square and sequentially sifting through the litter and soil to a desired depth. The material is sifted over a white collecting tray using a sieve, and works best for collecting larger arthropods such as Coleoptera, which are beetles. Beating requires a collecting tray or beating sheet placed between a suitable piece of flora, generally a shrub. The collector beats the flora and collects all the arthropods or other insects that drop onto the tray or sheet when disturbed. An aspirator is used to collect insects and arthropods visually spotted in the searching method. Finally, all specimens collected through any of these methods are placed into the killing jar of the collector's choice (Resources Inventory Committee).

Pitfall Trap

A pitfall trap is used to collect any insect or arthropod that walks on the ground, and consists of a cup or container sunk into the ground and half filled with a killing agent, which is usually a mixture of ethanol and propylene glycol, antifreeze. Dentonium benzoate is often added to ground-based traps to deter mammals from drinking the fluid. Guide vanes can be sunk in the ground in equal increments around a single trap or singly between two traps. A cover can be placed overtop to keep out rainwater. Pitfall traps are often nested, where a smaller cup with killing agent is placed inside a slightly larger empty cup, to save trap contents in case of rain (MacGown).

Berlese Funnels

Berlese funnels are used to collect arthropods from soil and leaf litter. There are many variations, but in general a Berlese funnel consists of a covered bucket with a large funnel that fits down inside. A light is attached to the underside of the cover, and a wire mesh screen is placed at a distance in the funnel. A sample of soil or litter is placed on the screen, the light turned on, and the cover attached. A killing jar is attached to the end of the funnel after the sample is placed in the funnel, as some material inevitably falls through the screen. The killing agent varies depending on specimens wanted, but is most often a mixture of ethanol. Most arthropods within soil and litter do not like light or dry soil, so the light will force arthropods down through the sample into the jar at the end. ("Collecting and Preserving").

Pan Traps

Pan traps are used to capture micro Hymenoptera, which are tiny wasps, bees and ants. Pan traps consist of colored pans filled with soapy water. Different colors will catch different types of insects, the most common colors being yellow, blue, white, and red. Pan traps work on the principle of surface tension. The soap lowers the surface tension of the water that many Hymenoptera normally use to cross liquid. Since the surface tension is lowered, they fall into the soapy water. If the collector is looking for arthropods, the water is poured through a fine aquarium mesh net during the manual sorting process and the specimens are rinsed with ethanol. (MacGown)

Flight Interception and Malaise Trap

A flight interception trap consists of a screen or other kind of barrier placed across flight lines with a pan placed underneath, and is useful for catching insects that tend to fly downwards when hitting a barrier, such as Coleoptera. The pan generally is half filled with a preservative. Flight interception traps are often used in conjunction with malaise traps. A malaise trap consists of four black walls and a white roof peaked at one or both ends. A killing jar is placed in the peak or peaks to catch insects that tend to fly upwards when in contact with a barrier, such as Hymenoptera and Diptera, commonly known as flies. The tent is supported by poles. When used in conjunction with flight interception traps, pans are placed around the bottoms of the walls to catch the insects that go downwards. Flight intercept and malaise traps are ideally set up at right angles to an insect flight line, thus maximizing collection. Killing agents vary depending on specimens desired, but an ethanol mixture is most often used (MacGown).

Light Traps

Light traps are most commonly used to collect insects attracted to light, mainly Lepidoptera, which are mostly moths and butterflies. A light trap consists of a light, such as mercury-vapor, black-light, ultraviolet, or white light, and some kind of collection method. Collectors have a choice of two different gathering methods. Insects can be collected into a killing jar manually off a white sheet placed on the ground or hung in front of the light source. A funnel with attached killing jar hung below the light source will collect any insects that strike the light and fall through the funnel, into the bottom of the trap. Sometimes three mesh screens are utilized when collecting using a funnel to prevent damage by beetles. The screens get progressively smaller, thus limiting the size of insect to fall into the killing jar. The screen method is usually used in conjunction with a dry killing agent, and is most often used for moths. Beetle collectors prefer ethanol for this kind of light trap (Resources Inventory Committee).

Lindgren Funnel Trap

A Lindgren funnel trap mimics standing trees and are excellent for collecting wood boring beetles. The trap consists of a series of hanging black funnels suspended one on top of the other with a killing jar placed at the very bottom. Sometimes these traps are baited with bark beetle pheromones or turpentine. For this trap, ethanol or ethanol/propylene glycol mix is most commonly used as a killing agent. The smell of the ethanol helps attract the beetles. When the trap is baited, it is also called a "bait trap". A bait trap is basically any trap that has bait. The bait itself is often used as the agent to hold insects and arthropods. Bait used will vary depending on the kinds of specimens to be collected (MacGown).

4.2.2. Separation of Specimens

After the parataxonomists return from the field with specimens, the newly collected material is separated into various groups. First, most of the large specimens such as the butterflies, moths, and beetles are taken out and dried. The butterflies and moths must be stretched and held in place with a combination of tape and pins, so that when they are dried all of the features can be seen. Once they are dried, they are sorted into groups and pinned to styrofoam boards within a wooden drawer with a glass top. Each specimen is paired with a unique barcode and entered into the computer database, described in the following section. The drawer goes into the dry collection, which is sorted taxonomically. INBio's collection has over three million specimens, carefully air conditioned and kept clean, to best preserve them (Ulate).

The remaining material generally contains large numbers of very small specimens, including mites, ticks, insects, and worms. To exhaustively sort these would take a great deal of time and resources. In addition, many specimens such as spiders cannot be dried without collapsing. Instead, all of the remaining specimens for each trap are put in a single jar of alcohol and stored for later sorting. This is called the wet collection. Once the jars are put into the wet collection, they remain there until scientists need to sort them for a certain type of specimen.

For example, as volunteers for INBio, our primary contribution is to help with the separation of Oonopidae spiders. The Museum of Natural History in New York recently began a project, studying this particular family, which according to Carlos Viquez has not been thoroughly studied in nearly fifty years. Viquez is INBio's spider expert, and is partnering with the museum in their worldwide endeavor. Our part is to search the wet collection for jars that might have Oonopidae within, and separate out the desired specimens. Many jars have already been combed for spiders, allowing us to simply sort through the presorted vial, rather than looking through the entire jar. Other jars have not been presorted, so while we are looking for Oonopidae specifically, we also separate out all of the other spiders for the sake of future studies. The primary interest of this project is to gain a better understanding of the taxonomy and geography of Oonopidae. It is also conceivable that the bio-prospecting unit may find a future use for the silk from a certain type of spider, or perhaps the scutes on the Oonopidae will contain some valuable chemical that may revolutionize the world. Any positive effect from a usable specimen that INBio discovers will possibly help farmers, pharmacists or some other branch of science.

To sort through a jar or vial full of specimens, the material is dumped into a petri dish. Jars and large vials contain too much to put into one dish, so one spoonful is sorted at a time. The specimens in the dish are covered with alcohol, thus preventing decomposition and also dust from collecting on the specimens. The alcohol works as a looking glass, to keep the specimen clear while under magnification. A stereoscope is then used to sort through all the matter in the petri dish. A stereoscope is similar to a microscope, except that it delivers three dimensional images rather than two. It accomplishes this by changing the angle from the line of sight of each eye. A box with two bendable lights is used to illuminate specimens at needed angles. Depending on what is found in the jar, at the end there will be three containers: the original will have all the material besides spiders, one vial will have Oonopidae, and the final vial will have all other spiders. Labels must be carefully copied for each extra vial. Once finished with a vial or jar, all vials in use are filled with alcohol. For the current study, the Oonopidae are set aside, and the rest of the material is returned to the appropriate places within the wet collection.

Once the Oonopidae are separated from the collection, they are then sorted according to a biological key for genera. A biological key takes one feature and uses that as a beginning to separate out genera. For example, number one on the key might say, "Does the spider have less than six eyes? If yes, go to number 2. If no, go to number 3." This is continued for successive features until all genera have been uniquely identified. Once the genus of each specimen is identified, another key is used to identify species for each genus. Since this study is being conducted at the American Museum of Natural History, all of the pre-identified Oonopidae specimens are sent to the museum in New York. There they will be combined and compared with all of the other specimens gathered from around the world. Given the length of time since these spiders have been studied, in addition to the known diversity within the family and the wide range of locations where they are found, it is inevitable that many new species will be found and described as a result of this study.

4.2.3. Computer Database

After collecting, sorting and preserving the specimens, and before identifying them and putting them into the collection, each specimen is uniquely identified with a barcode. This barcode corresponds with an entry in the Atta database, which allows INBio to take advantage of the organizational power of computers. The database ties together all of the relevant information of each specimen: the type of trap; the date the trap was set and collected; the altitude measured on site; the geographic coordinates; the collector's name; and any relevant notes from the collector's log. Once the specimen is identified at each taxonomic level, this information is added to the database entry.

Atta, the name of the database system, was developed by INBio's Informatics Development unit, which is currently headed by William Ulate. The database itself is a single system, designed to handle all of the information necessary not only for arthropods, but also for molluscs, nematodes, plants, and fungi. However, for the convenience of each scientist, the interface has been customized to give each user only relevant information. The entire database of over 3,000,000 specimens is also available online, free of charge, to the general public. INBio frequently collaborates with other organizations, sharing its entire database. (Ulate)

Perhaps the most useful part of INBio's database stems from the fact that every specimen is pinpointed geographically. This allows it to be easily plotted on a Geographic Information System. In fact, this function is so important that INBio has an entire department dedicated to working with GIS. The data for each specimen is mapped and combined with other maps, such as topography, ecosystem types, road maps, etc. These maps are quite useful in making connections between various pieces of data. GIS also helps INBio to strategize by showing where they lack samples, what types of ecosystems are relatively unknown, and what locations similar species are likely to be found. Finally, GIS is one very practical way that INBio frequently works with SINAC, putting together maps and observing correlations that directly affect the management of the national parks. In this way, the knowledge gained by INBio is applied in the conservation system. This is one of the many connections between "Save" and "Know".

4.2.4. Description of New Species

Quite often, new specimens are collected that do not fit any known species. If these specimens represent a species that is known but not included in the key, the key is revised. This would happen if the key was designed for species found specifically in one area, such as Central America, and the particular species had previously not been found in that area. Sometimes, these specimens do not fit into any known species of the genus. When this happens, the taxonomist will look at all literature available, to make sure that the specimen in question has never been described in the past 150 years of reliable scientific study. If no description is found, a new species has been discovered. Naming of a new species is the responsibility of the first person to discover that species. The taxonomist picks a Latin-based name for the new species. The International Commission on Zoological Nomenclature (ICZN) is responsible for making sure that the names are unique (Coppard). The taxonomist writes a description that must be detailed enough to positively identify any other member of the species. To make the name the official name of the species, the taxonomist publishes it with the description in a recognized journal. Occasionally, although much less frequently, a new genus is discovered, necessitating the same process of research, description, and naming. The entire process must be done with great care and precision, to ensure that there is exactly one scientific name for each species. Accordingly, naming of new species is generally left to recognized experts. Due to insufficient funding and time, INBio currently has scores of unnamed specimens, lacking only the expert manpower to do the necessary research and description, thereby introducing them to the scientific community (Lewis).

There are millions of current species and approximately 15,000 newly discovered ones each year. Such a large volume of information creates occasional problems and ambiguities. A species might be classified more than one way or classified by more than one person or organization. The ICZN attempts to resolve these issues though publishing the discussion of various experts in the species area of interest. The ICZN is a member of the International Union of Biological Sciences, as well as an English non-profit company created in 1947 (Coppard).

From 2000 to the present (March of 2007), Art Borken and Monty Wood have been working with a group of about 60 other entomologists from around the world. Their goal, nearly complete, is to compile a book describing every known genus of fly in Central America. Even though this classification is only to the genus level, it lays the framework for further study of all species within each genus. Until now, there has not been any such book. With its completion, entomologists have a more thorough base from which to begin further study or classification of Central American Diptera. In fact, in the process of compiling this book, Wood focused on one particular genus. He came across many new species, some of which he has informally named but has not yet been able to describe and publish. Once this book is completed, he will have a chance to continue with the process of officially naming and describing his newly discovered species.

4.2.5. Further Study

Once a specimen has been identified, it is then studied at the leisure of scientists to discover more about it. This is done in many different ways by different scientists, depending on the resources available and the specific information desired. Currently, INBio's beetle unit, Coleoptera, has a program where they are growing several generations of beetle from egg into adulthood. Headed by Carlos Hernandez, this program is helping scientists learn more about how each beetle fits into the environment. For example, beetle larvae are quite important in the decomposition of organic material. In the laboratory, scientists are able to determine what stage of decomposition they thrive in; measure how much organic matter is processed by each stage of larvae; and test the resulting soil for mineral and organic content. Each stage of larvae growth is documented with pictures and measurements. As a result of this study, scientists are coming to understand what factors affect the beetles at each stage, how fragile they are, and how they fit into their ecosystem.

4.2.6. Educational Programs

To succeed in the effort to conserve biodiversity, it is not enough to simply collect information. This information must be effectively applied by government policy makers, Non Government Organizations (NGOs), local businesses, land owners, and consumers. Therefore, the information that is generated by INBio must be placed in the hands of each of these groups. With this in mind, INBio has several departments that are dedicated to education.

INBioparque was created not only with revenue in mind but also to educate the public about Costa Rica's natural resources. Education is a lifelong process. It is especially important to educate children of the importance of conservation at a young age. *INBioparque* contains an "Open Classroom" that consists of factual displays and interactive elements, such as a bicycle generator powering a light bulb. They have programs and content suitable for all ages from elementary school to college, as well as programs for teachers ("Educational Programs"). *INBioparque* is concerned with increasing the bio-literacy rate among Costa Ricans and the entire world. The more understanding that the general public has about the world's waning biodiversity, the more likely they are to change current trends. *INBioparque* even has an area on renewable energy resources. The education that INBio is trying to provide suggests that the consumption that most of the world currently enjoys is not the most feasible long term solution. *INBioparque* suggests there are alternatives to the standards of consumption, such as solar and wind power. The interactive examples employed throughout the park are a testament to the importance of ecological conservation and sustainable living.

There are a number of publications that Editorial INBio publishes for educational purposes. These products range from textbook style material for elementary school children to bird and plant guides for tourists. Editorial INBio was also created to educate the public about biodiversity and the conservation necessary to sustain Costa Rica's unique resources. In the past six years, Editorial INBio has published over 120 titles. The detailed information in the Atta database about specimen location allows their guides to be very accurately detailed and know the specific ranges of a number of species. They have also produced more than 30 educational resources for teachers ("Editorial INBio"). Most of these materials are published in Spanish and apply specifically to Costa Rican geography. Ideally, every country would have a comparable institution so that everyone has access to information about local ecosystems.

INBio offers a number of services to the public besides education such as consulting. Making use of the large amount of experience that INBio has dealing with various conservation issues, they are able to sell their knowledge and advice to aid the sustainable future of Costa Rica. Some of the areas of the business consulting expertise that INBio offers are: bioprospecting, conservation, ecotourism, environmental education, environmental services, and economic evaluation ("Services"). The consultation that INBio offers aids in the practical conservation of Costa Rica's natural resources.

INBio also has a small communication department charged with publicizing the work that INBio does and maximizing its positive appearances. They work to organize interviews and conferences between INBio staff and outside media sources so that the work of INBio may be better known ("What is INBio?").

4.3. Use

The third and final leg of the strategy followed by INBio specifically and Costa Rica as a whole is the sustainable use of biodiversity. Biodiversity has been used throughout human history. Common resources such as food, clean water, and wood are all ancient uses for biodiversity. Many other uses exist, most notably ecotourism and bioprospecting. It would be impossible, at least in the near future, for mankind to stop using biodiversity; we cannot yet make ourselves utterly independent of the ecosystems within which we live. However, for conservation to succeed we must somehow use biodiversity in such a way so as not to destroy it by using it faster than the replenishment rate. This is a very complicated issue, especially with the world's growing population and the general trend toward economic growth and increased consumption.

INBio itself does not work directly within this part of the strategy. However, INBio's primary goal is the successful conservation and sustainable use of biodiversity. They seek the knowledge necessary to understand and overcome this complicated problem. Practically all of the information gathered is in some way related to the use of biodiversity, but certain disciplines are more directly related than others. In this section, we will describe ecotourism and bioprospecting, detailing what they are, how they fit in conservation, and what INBio does with each.

4.3.1. Ecotourism

Ecological tourism, commonly called ecotourism, is a very popular use for biodiversity, especially in Costa Rica. For this particular country, ecotourism is the number one foreign revenue producer. Over the past several decades, as the environment has grown in importance in the public mind, ecotourism has risen as an industry that capitalizes upon the combination of great ecological wealth and people willing to pay to see it (Van Tassell). The government cooperates with this industry by building trails in certain sections of the national parks and charging entrance fees. In addition, many other organizations and businesses are involved in ecotourism by providing tours, transportation, and exciting experiences highlighting the ecological wonders that Costa Rica offers.

Ecotourism can be an excellent way to promote the preservation of valuable ecosystems, if done properly with careful attention to sustainability. However, it is often not done with enough attention to the long term affects, looking only to see the short term profit that can be made. In so doing, it is liable to destroy the very environment that it is based upon (Van Tassell). To be sustainable, ecotourism must be combined with a thorough understanding of the local ecosystem, so that it can be appreciated without being exploited and destroyed. This knowledge is what INBio seeks to provide.

INBio offers consultation services to the government and businesses on the topics of conservation and ecotourism. They actively seek to put the information they gather into the hands of people who are able to implement sustainable use of the environment. SINAC and INBio work together in attempting to conserve the natural resources and create a Costa Rica that is more attractive for tourists (Matamoros). Through investigation of the species that live in the various national parks by INBio staff, SINAC is better able to market the biodiversity that each of its parks contain. There are also many local guides at many of the national parks that intimately know their local biodiversity and are able to work and share their knowledge with tourists, while at the same time contributing to the national ecotourism income.

4.3.2. Bioprospecting

Bioprospecting is the process of looking for useful and economically valuable chemicals, genes, proteins and microorganisms from some form of biology. INBio has found many useful products in several markets from its wealth of biology samples. According to one of INBio's bioprospecting staff, it takes on average 17 years to find one useful product, refining and testing it until it is ready for the market. This is a very tedious process with many payoffs such as finding sustainable sources of useful compounds which may allow a product to be available for as long as it is needed.

Most notably and important to the health and welfare of the world is the pharmaceutical arena. Throughout INBio's short history they have enjoyed contracts with a number of reputable pharmaceutical companies, such as Merck, Bristol Myers Squibb, STRATHCLYDE, Indena and Eli Lilly and Co. (Gámez 11). Finding cures to diseases and medications that prolong and promote an active life is a continual goal of the world of medicine. Indena, for example, is an Italian company that is most interested in finding uses for plants. They search for chemicals, reactions, and active principles or methods derived from plants to create products suitable for the pharmaceutical, health-food and cosmetic industries (Indena). They utilize resources from over 40 countries to acquire a diverse collection of plant organisms that may be useful. One of the interesting parts of Indena is their current work with anti-cancer treatments. They were able to develop the drug Paclitaxel, which has been used to successfully treat cancer patients and was derived from plants (Indena). This connection between INBio and Indena illustrates the relevance of bio-prospecting and plant gathering to helping society with complex problems like cancer. Since tropical forests contain so much unstudied life, it is likely that many more medications and cures exist. This potential is one compelling reason for the conservation of biodiversity, especially in Costa Rica. With proper planning and conservation practices, it is hoped that such useful organisms will be available for the benefit of future generations.

Many products of the tropical rain forests also have cosmetic value. Physical appearance is a major market in much of North America and Europe. Costa Rica with its unique ecosystems has a number of compounds that are of interest to cosmetics companies. Contracts have occurred with Indena and GIVAUDAN ROURE (Gámez 12). As long as make-up and other aids to physical appearance continue to be a major industry, there will be demand for new and unique products that accentuate the attributes humans wish to display.

Agriculture is another market segment that involves the use of chemicals designed to enhance crop growth and prohibit the destruction of valuable crops by insects and weeds. Useful pesticides and herbicides are often later found to be harmful to the ecosystem, for example DDT in the 1960's and 1970's. Therefore, the search continues for new ecologically friendly chemicals. INBio has worked on contracts with BTG and ECOS as well as working with the University of Massachusetts from 1995 to 1998 (Gámez 12). These collaborations help to make agriculture more productive and sustainable for the growing world population.

Biotechnology companies have also benefited from contracts with INBio. Many of these biotechnology companies are centered in the United States. There have been contracts with ECOSCIENCE, RECOMBINANT BIOCATALYSIS, DIVERSA, PHYTERA Inc., and AKKADIX (Gámez 12). Biology is one branch of science with incredible potential that is just beginning to be tapped. Working with all of the resources that INBio has is clearly a useful method to gather new material and achieve productive results.

The Biodiversity Prospecting unit at INBio has contributed significantly to its reliable income. From 1998 to 2002, the Bioprospecting department required an investment of 3.8 million dollars and returned during that same period an income of 4.9 million dollars ("Toward a Sustainable INBio." 28). This influx of funding has allowed other non-producing departments to remain open such as the arthropod department.

5. Observations

Throughout the process of studying INBio and working with the local staff, we have made many noteworthy observations. In general, we are impressed with INBio's work. Through the years we have heard many people talk about sustainability, with a general attitude of hopelessness and despair. It seems that people are quick to say something must be done, but few people know where to start. INBio is at the forefront showing the world how to begin. They do this through a myriad of methods, all based on the "Save, Know, Use" philosophy. INBio itself focuses on the creation and collection of any information that will help the cause. INBio then seeks to put this "know" into the hands of those who are in the position to "save" and "use" biodiversity, namely lawmakers, NGOs, business owners, educators, and the general public.

5.1. The Importance of Conservation

First of all, our research and interactions with other researchers have convinced us of the absolute necessity of the work that INBio is conducting. The fundamental issue at stake is the sustainability of human society as a whole. This is reflected in such topics as deforestation, global climate change, the extinction of species and entire ecosystems, depletion of oil reserves, etc. In particular, Costa Rica is interested in how sustainability and biodiversity relate, since this is the primary gift with which it has been endowed. Sustainability and biodiversity meet in the realm of conservation. Accordingly, INBio's mission and vision are centered on the achievement of conserving biodiversity in a sustainable manner.

The conservation of biodiversity is of the utmost importance for many reasons. As the human race, we depend on the environment for our sustenance. If we over-exploit that environment, destroying the ecosystems within, we remove its ability to sustain us. For example, rainforests are a significant factor in cleaning the atmosphere of carbon dioxide. All plants use and store carbon dioxide in the process of photosynthesis. The enormous density of plants located in rainforests make this location very powerful in cleaning large amounts of carbon dioxide out of the atmosphere. When we destroy the forests we decrease the earth's ability to store carbon and release oxygen.

As the world population grows exponentially, new sustainable living methods need to be devised. It will not be possible to continue to cut down the world's rainforests at the current rate, because they will cease to exist in less than 40 years ("Rainforest Facts"). Everything INBio does from conserving electricity to using mugs instead of styrofoam cups shows their commitment to developing a “green” working environment. It is also important that INBio participate in education of all ages because people will only care about saving the world if they know that it is in trouble.

Costa Rica’s rich biodiversity is reflected in both animals and plants. There is a great deal of flora and fauna hidden in the rainforests, unknown to modern science. With these unknown species come nearly limitless possibilities of discovering cures for various diseases and afflictions. Rainforest ecosystems are an indicator of the world's health. As the volume and diversity of rainforests decrease, the world is learning that it cannot continue as it has throughout the past century. INBio is attempting to know what happens in these threatened ecosystems so that we may use the natural resources and stop the harmful practices that have become commonplace. For example, the larvae of many insect species actually make dirt from organic material, releasing nutrients necessary for plant growth (Hernandez). Not many people understand the necessity of insects for the continuation of life, but without dirt it is easy to see that the world would be very different. Forests, especially rainforests, desperately need soil so that plants are able to take root and use the multitude of nutrients available in the excrement of lowly insects.

Modern thought of rainforests as economic resources is slowly destroying beautiful and healthy rainforest ecosystems. Deforestation is devastating, especially clear cutting, as the land is stripped of all lumber. Much of the land formerly occupied by rainforests throughout the world has been clear-cut or deforested by other methods for resorts, ranching, farming, and development. The rainforests once covered 14 percent of the land surface of the earth, but now cover a meager six percent ("Rainforest Facts"). Costa Rica, while suffering from these problems, is still a world leader compared to many other countries which have a far greater problem with deforestation. Scientists can only guess at the number of species threatened or already extinct.

An unfortunate effect of the destruction of forests is also economic. The destruction of forest and rampant tourism inside a limited number of small parks has caused the animals to flee to more remote areas. The decline in animals will not be looked upon favorably by tourists, potentially decreasing significantly Costa Rica's largest source of foreign income. This problem has already begun to be addressed in some of the national parks such as *Monteverde* where the limit of visitors is kept at 100 people or fewer in the park at all times. This allows for a more natural experience. The low number of guests at any given time disturbs the wildlife less than an unregulated flow of tourists. The same is also true for other parks, and some such as *Cerro Chirripó* even require reservations far in advance.

Of the approximately 1.4 million known species, only about one percent have been significantly studied. It is also estimated that there are between 3 and 30 million species in the biosphere, leaving at least half of the species in the world to be discovered ("Species"). This large amount of unknown life means that we cannot begin to understand the world as a whole or our effect on it. As evidenced by the Rocky Mountain National Park example in the introduction, we influence the world we live in. With so many unknown species, it is not possible to know our effect on all of them and how they affect ecosystems. The more we know about the world the better we can save it for future generations.

5.2. Commendable Progress

Organizations like INBio and MINAE are working to preserve, conserve, and protect the remaining rainforests and ecosystems of Costa Rica. Using the powers of the government, MINAE is actively trying to protect land so that it can be researched in due time by organizations like INBio. By combining the search for sustainable economically and environmentally friendly practices with education of the public, INBio is leading the way for sustainable conservation of our world's natural resources. Before we can understand how to productively and sustainably modify our environment we must know what exists within it. This is why the diverse and detailed collection that INBio has is so valuable. Ideally, INBio would have specimens of every species in Costa Rica and would know how each species works with the others in its ecosystem. They would also be able to know what human byproducts affect every species, and provide the information necessary to engineer ways of modifying our behavior accordingly. As humans possessing the unique ability to change our behavior, it is our duty to develop sustainable practices to live in symbiosis with nature.

Our volunteer work helps to keep INBio up and running by aiding where needed without requesting funding for our help. Our knowledge of scientific practices and methods has grown significantly, aided by the friendly culture of Costa Rica. Students from around the world do and will continue to benefit from volunteering at INBio in many areas. We have met volunteer students from Germany, Canada, Italy, Spain, and the United States who are all interested in INBio's work and sustainability.

INBio is more than a lab; it is a tool for educating the public to the wonders of the natural world. The most successful way to stop the consumption of the world is through education of all ages in all areas of life. It is a weapon against the loss and destruction of valuable land. It is a resource for scientists from all over the world to study the diversity of the rainforest ecosystem through access to collections and ongoing research of various families and genera. However, INBio is also a business, and as such it needs the world's help to continue and expand its areas of operation to many more ecosystems and places currently unstudied.

5.3. Challenges Faced

Ecotourism is one of the main national incomes for Costa Rica and as a consequence is very important. If the trend of large new developments persists the animals will leave and so shall the tourists. While people enjoy clean hotels and lavish services such as air conditioning and swimming pools, the majority of people are attracted to Costa Rica for its biodiversity. There are hundreds of species of orchids and birds as well as exotic animals such as monkeys and sloths. Tourism has to learn how to coexist with animals and their habitat. The current trend is one favoring the tourists in the short term. While this strengthens the current economy, it cannot last forever with the diminishing accessibility to the most interesting animals. A low-impact long-term solution must be engineered.

Funding is continually a problem especially with such a unique venture as INBio. Several years ago, INBio leadership set a goal for 66% income from services and 33% soft funds, which consists of donations and grants and are not as dependable as earned income. Earned income comes primarily from three sources: INBioparque, Editorial INBio, and Bioprospecting. *INBioparque* was created to generate revenue for to fund the other non-revenue earning units, but has allegedly not fulfilled that goal (Wood). That is not to say that *INBioparque* is a failure; it is also designed to educate the public, which it does accomplish. Editorial INBio has also failed to be a monetarily productive venture due to the amount of resources needed to complete one publication and the relatively saturated market of biology field guides and other publications. Bioprospecting has generated money, but since 17 years is needed to develop a marketable product, it is a long term investment with less than desirable yearly profits. Due to economic forces, INBio's part of bioprospecting, the discovery phase, is undervalued monetarily. The research departments, like the arthropod unit, do not directly produce any revenue while consuming money for salaries, collection maintenance and equipment. The continuous research of new species is essential to INBio's mission, so it must not be stopped but cannot pay for itself.

Several North Americans have alluded to the fact that INBio is slow to ask for donations. In 2006, INBio's income was 85% earned services and 15% soft funds, or donations and grants (Ulate). This either means that they are earning more than they expected, or they are not receiving as many donations as hoped. Many major grants have ended recently, and accordingly many valuable staff members have had to be let go because their salaries were no longer covered. Several years ago, INBio set its ideal size at 200 to 220 employees. At the time, they had 240, but they now have only 175. Now they are reconsidering how much they should depend on soft funds, with an eye toward the future and financial independence. Should they make an effort to seek out donations, or would it be better to search for more revenue generating activities? In North America, it is normal for non-profit organizations to rely extensively on donations, and to have many staff members dedicated to grant writing and fundraising. From a North American perspective, it seems that INBio is missing out on many lucrative funding sources that would greatly help in completing its mission.

6. Conclusion

The sustainability of life is a major concern in the scientific world. Primarily, we humans are concerned with our own future survival. As a species, we fit in and depend on many ecosystems which we in turn manipulate to suit our wants and needs. In the long run, human survival is dependent on the sustainable conservation of these ecosystems within which we belong. However, current trends are leading to the destruction of ecosystems all around the world. For this reason, many scientists and visionaries have started to speak up about how we need to change our ways. There is little arguing with that fact. The question facing humanity is: what exactly must be done?

In many ways, Costa Rica is a test case. The world is watching as this little country explores the possibilities in conserving and thriving amidst incredible biodiversity. In this nation, a wealth of life is combined with a peaceful, unobtrusive national identity. When this was placed in the context of the current sustainability issue, conservation quickly became a national priority. INBio is one piece of the national endeavor to develop successful models for the conservation of biodiversity. By working to conserve Costa Rica's rainforests, INBio is working to conserve the world for future generations. INBio's role is primarily the gathering and dissemination of information. They collect, classify, name, and study all manner of life forms. They seek to make connections with this information, relating businesses and government policy with the biodiversity that they affect. They also search for potential uses of plants and chemicals found through bioprospecting. INBio then seeks to place this information in the hands of whoever is in position to use it: politicians, businessmen, scientists, and the general public. Their work in sustainable ecologically friendly economic activities provides a compromise between the world and the needs of humanity by allowing humans to thrive along with the species of Costa Rica.

While completing this project, we have been volunteering within the Arthropod department of INBio. Our primary contribution has been in the area of spiders, sorting out the Oonopidae family from the wet collection as well as working on various other ongoing projects. Our work with spiders might seem trivial, but they are an essential albeit small part of a complex web of ecological interconnections. Spiders themselves are an incredibly diverse order within the animal kingdom, found in almost all terrestrial ecosystems. To understand the ecosystem as a whole, we must know what participates in it and the function of each element. Rainforests, the most diverse ecosystems on the planet, are so complex that we only have estimates of the number of species living within. In our study of spiders, we have done our part helping to increase the overall knowledge, that will eventually culminate in a global sustainable society.

INBio is a delicate resource. Financially INBio is not quite independent even with their trust fund and the revenue from bioprospecting, INBio editorial and *INBioparque*. This is one reason why INBio accommodates so many volunteers, around 150 annually, with only 175 staff (Matamoros). While INBio is on the way to becoming a financially independent non-profit organization, volunteers greatly increase the efficiency and overall accomplishment. For example, professional taxonomists have donated over 24,000 days worth around $9.7 million, to the classification and study of INBio's collection ("Toward a sustainable INBio" 26). Other volunteers also helpful, such as scientifically minded WPI students. After spending nine weeks among this organization we recommend more projects take advantage of the opportunities presented. Given the importance of the mission that INBio is fulfilling for the future of the country, which it is modeling for the entire world, every effort must be made to support INBio. Possible connections exist for biotechnical and pharmaceutical collaboration, financial donation, ecosystem research and detailed taxonomic study.

7. A1 – Biodiversity by Country

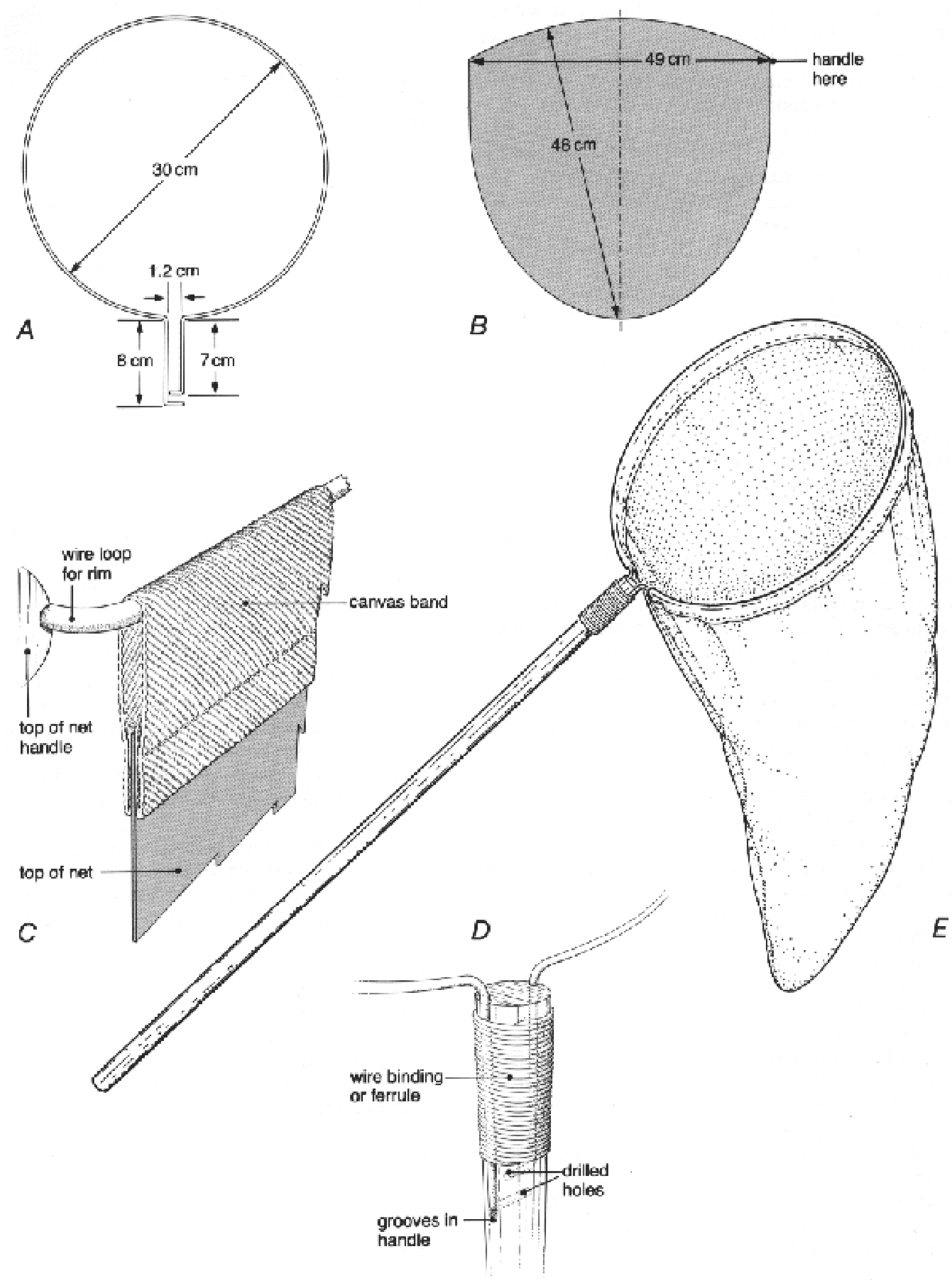
Total number of amphibian, bird, mammal, reptile, and vascular plant species, by country

Brazil	59,851	Panama	11,484	Brunei Darussalam	6,644
Colombia	54,649	Argentina	11,285	Uganda	6,492
China	34,687	Madagascar	10,541	Japan	6,484
Indonesia	32,680	Philippines	10,127	Italy	6,309
Mexico	28,836	Guatemala	9,927	Bhutan	6,216
South Africa	25,052	Cameroon	9,921	Nigeria	6,132
Venezuela	23,429	Laos	9,411	Suriname	6,122
Ecuador	22,065	Turkey	9,387	Dominican Rep	6,072
United States	21,474	Paraguay	8,935	Chile	6,059
India	21,020	Iran	8,899	Zambia	5,981
Peru	20,081	Myanmar	8,709	Pakistan	5,977
Bolivia	19,561	Nicaragua	8,642	Bangladesh	5,871
Australia	17,974	Kenya	8,353	Spain	5,796
Malaysia	17,171	Nepal	8,213	Haiti	5,716
Costa Rica	13,630	Ethiopia	8,011	Portugal	5,714
Thailand	13,340	Guyana	7,672		
Papua New Guinea	13,115	Gabon	7,620		
		Cuba	7,159		
Congo, Dem Rep	13,107	Congo	6,970		
		Honduras	6,894		
Russian Federation	12,468	Mozambique	6,859		
		Angola	6,731		
Viet Nam	12,034	Kazakhstan	6,708		
Tanzania	11,906	French Guiana	6,689		

Source: World Conservation Monitoring Centre of the United Nations Environment Programme (UNEP-WCMC), 2004. Species Data (unpublished, September 2004).

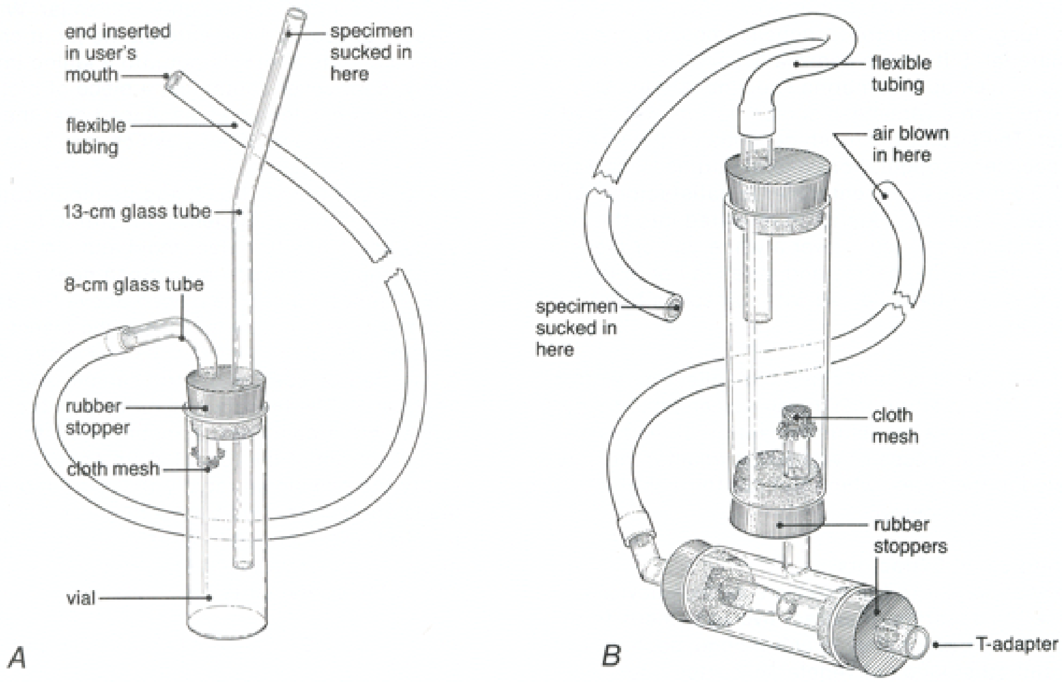
8. A2 - Tools and Traps

Aerial Net



A through E: Steps to construct aerial net
Source: “Collecting and Preserving Insects and Mites: Tools and Techniques”

Aspirator

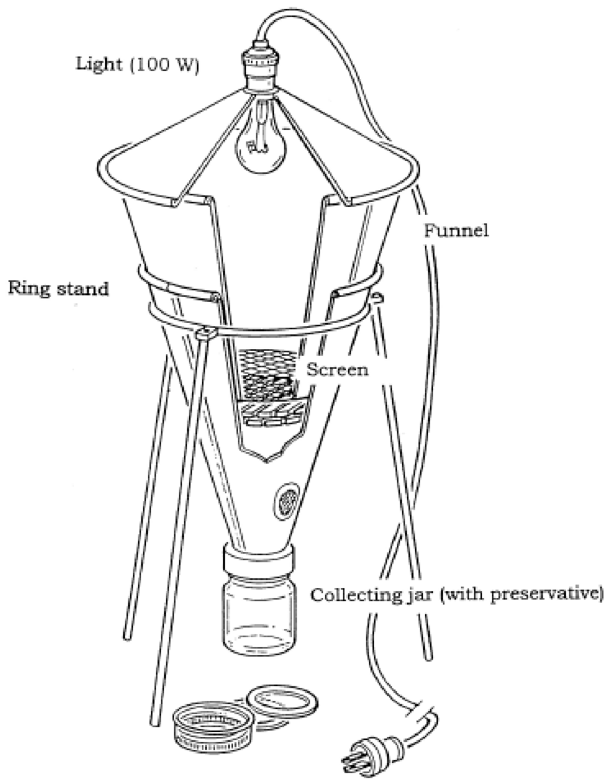


A) Requires suction by collector, B) Requires blowing by collector
Source: “Collecting and Preserving Insects and Mites: Tools and Techniques”

Beating Sheet

Source: MacGown, Joe. “Insect Collection Methods”

Berlese Funnel Trap



Source: Resources Inventory Committee

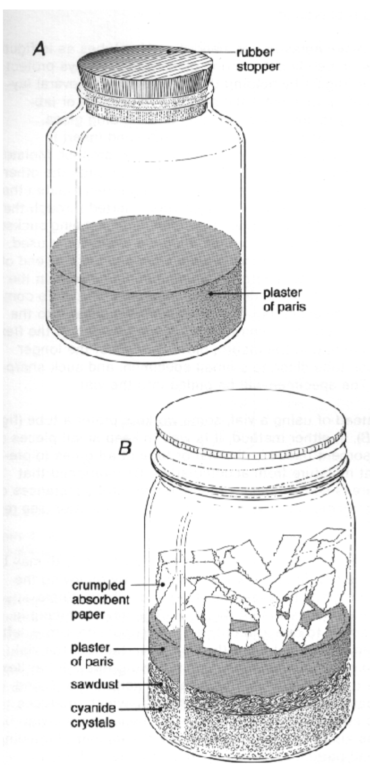
Collecting Tray

Collecting Tray with Forceps
Source: Amanda Pollack, 18 April 2007

Flight Interception Trap

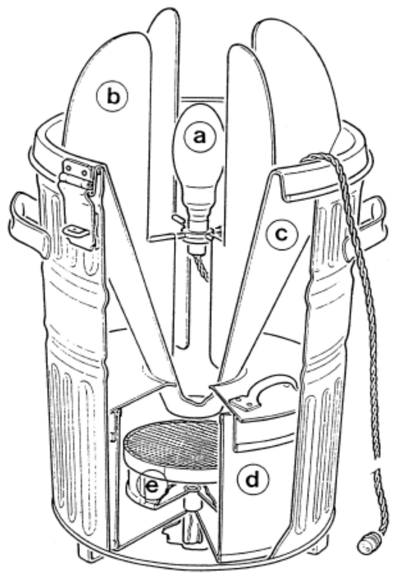
Source: "Collecting Methods". California Beetle Project

Killing Jar



A) For use with liquid killing agent, B) For use with solid killing agent
Source: "Collecting and Preserving Insects and Mites: Tools and Techniques"

Light Trap, With funnel



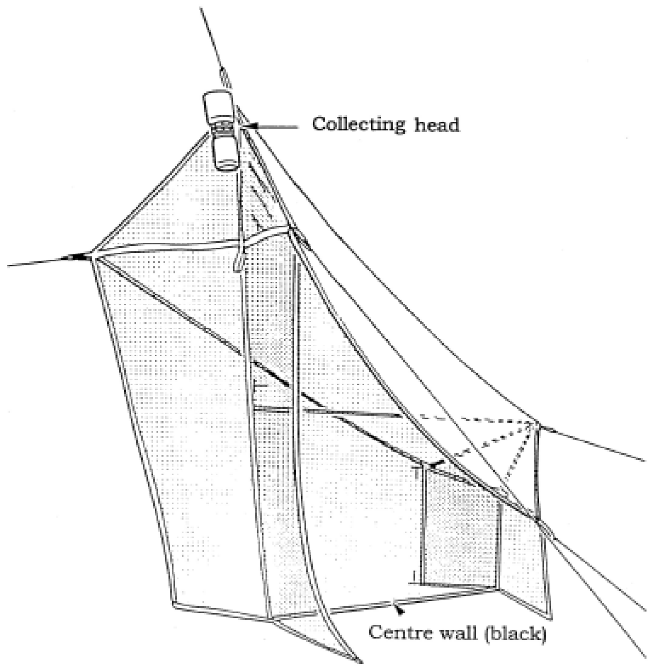
a) Light source, b) four metal baffles, c) funnel, d) inner killing chamber, e) rain drain with tube leading outside trap

Source: Resources Inventory Committee

Lindgren Funnel Trap

Source: Pherotech

Malaise Trap



Source: Resources Inventory Committee

Pan Trap

Source: Peter T. Oboyski

Pitfall Trap

Pitfall traps separated by steel guide vane
Source: MacGown, Joe. “Insect Collection Methods”

9. Works Cited

Armstrong, W.P. "Major Phyla of Animals." waynesword.palomar.edu. November 2001. Palomar College. 12 April 2007. <http://waynesword.palomar.edu/trnov01.htm>

"Arthropods." *What is INBio*. 21 March 2007. Instituto Nacional de Biodiversidad. 18 April 2007. <http://www.inbio.ac.cr/en/inbio/inb_artropodos.htm>.

Baker, Christopher. "Ecosystems". *Flora of Costa Rica*. 2005. Centralamerica.com Corp. 18 Feb. 2007 <http://centralamerica.com/cr/moon/moflora.htm>.

"Biodiversity in Costa Rica". 21 March 2007. Instituto National de Biodiversidad. 21 March 2007 <http://www.inbio.ac.cr/en/biod/bio_biodiver.htm>.

Borken, Art. Personal Interview. 15 March 2007.

Butler, Rhett A. "Rainforest Canopy - Epiphytes." Mongabay.com. 9 Jan. 2006. 26 Feb. 2007 <http://rainforests.mongabay.com/0405.htm>.

Butler, Rhett A. "Rainforest Canopy - Introduction." Mongabay.com. 9 Jan. 2006. 26 Feb. 2007 <http://rainforests.mongabay.com/0401.htm>.

Butler, Rhett A. "Rainforest Ecology." Mongabay.com. 9 Jan. 2006. 18 Feb. 2007 <http://rainforests.mongabay.com/amazon/rainforest_ecology.html>.

Butler, Rhett A. "Forest Floor - The Understory." Mongabay.com. 9 Jan. 2006. 26 Feb. 2007 <http://rainforests.mongabay.com/0501.htm>.

Chickering, Arthur M. "The Genus Ischnothyreus in Central America and the West Indies." Psyche. 75, 77-86, 1968.

"CIA – The World FactBook – Costa Rica". CIA World Factbook. 15 March 2007. CIA. 21 March 2007 <https://www.cia.gov/cia/publications/factbook/geos/cs.html>.

"Colorado wildlife officials press case for elk hunt in Rocky Mountain National Park". Boston Herald. 9 March 2007. Associated Press. 21 March 2007. <http://news.bostonherald.com/national/central/view.bg?articleid=187461&format=&page=1>.

"Collecting and Preserving Insects and Mites: Tools and Techniques." Agricultural Research Service. 19 October 2005. United States Department of Agriculture. 17 April 2007. <http://www.ars.usda.gov/Main/site_main.htm?docid=10141&page=2>.

"Collecting Methods." California Beetle Project. 2007. Santa Barbara Museum of Natural History. 18 April 2007. <http://www.sbnature.org/collections/invert/entom/cbpfieldwork2.php>.

"Costa Rica". Microsoft® Encarta® Online Encyclopedia 2007. 1993. April 10, 2007 <http://encarta.msn.com/encyclopedia_761572479/Costa_Rica.html>.

"Costa Rica National Parks and Reserves." 2004. World Headquarters. 17 April 2007. <http://www.worldheadquarters.com/cr/protected_areas/>.

"The Constitution of Costa Rica". Costa Rica Law. 2007. Costa Rica Legal Net. 21 March 2007 <http://www.costaricalaw.com/LEGALNET/constitutional_law/constitution_en.php>.

Coppard, Simon. International Center for Zoological Nomenclature. March 2007. International Trust for Zoological Nomenclature. 21 March 2007 <http://www.iczn.org/>.

"Costa Rica - History and Culture". 2006. interKnowledge Corp. 21 March 2007 <http://www.geographia.com/costa-rica/history.htm>.

"Costa Rica Travel Information". Costa Rica Map. 21 March 2007 <http://www.costaricamap.com/ing/info.html>.

"Ecosystem." Answers.com. 2007. Answers Corporation. 20 Mar. 2007. <Answers.com http://www.answers.com/topic/ecosystems-1>.

"Ecosystems: 2. How have ecosystem services and their uses changed?" GreenFacts. 8 Jan 2007. GreenFacts. 28 Feb. 2007 <http://www.greenfacts.org/ecosystems/millennium-assessment-2/2-ecosystem-services.htm#0>.

"Editorial INBio." Editorial INBio. 2007. INBio. 21 April 2007. <http://www.inbio.ac.cr/en/editorial/editorial.html?cat=1&pagina=1>.

"Educational Programs." *INBioparque*. 2002. INBio. 21 April 2007. <http://www.inbio.ac.cr/INBioparque/en/aula_abierta_en.html>.

Gámez, Rodrigo. "Algunos Resultados Del Trabajo Conjuto." Alianza INBio-SINAC. August, 2000.

Garcia, Randall. "Introduction to INBio for new employees". INBio headquarters, Santo Domingo de Heredia, Costa Rica. April 10, 2007.

Gray, Mike. "Biodiversity in Soil and Leaf Litter." Fact Sheets. 2003. Australian Museum. <http://www.amonline.net.au/factSheets/biodiversity_litter.htm>.

Hernandez, Carlos. Personal Interview. March and April 2007.

Hickman, C.P. and L.S. Roberts. *Biology of Animals*, Sixth Edition. Dubuque, Iowa: Wm.C.Brown Publishers, 1994. 25 March 2007, <http://www.cbs.umn.edu/class/spring2000/biol/2012/arthropd.htm>.

Hormiga, Gustavo. “Doctoral fellowships in spider systematics.” Arachnology. 13 December 2006. American Arachnological Society. 26 February 2007. <http://www.americanarachnology.org/AAS_bulletinBoard.html#doctoralFellowships>.

INBio. "What is INBio?". National Biodiversity Institute. 21 March 2007. 21 March 2007. <http://www.inbio.ac.cr/en/inbio/inb_antec.htm>.

Indena. "Indena S.p.A." 2005. Indena S.p.A. 17 April 2007. <http://www.indena.com/>

Infocostarica Staff. “Flora: An Overview”. Infocostarica S.A. 2006. 18 February 2007. <http://www.infocostarica.com/flora/general.html>.

"Informacion General." 11 April 2007. SINAC. 24 April 2007. <http://www.sinaccr.net/informacion.php>.

Land Resources National Program Center. "Summary of Acreage - All NPS." National Park Service. 31 December 2006.

Lewis, Jim. Personal Interview. March and April 2007.

López, Isaac. Personal Interview. 24 March 2007.

Matamoros, Vanessa. Personal Interview. March and April 2007.

MacGown, Joe. “Insect Collecting Methods.” Mississippi Entomological Museum. 9 April 2007. Mississippi Entomological Museum, Mississippi State University. 17 April 2007 <http://www.msstate.edu/org/mississippientmuseum/collecting.preparation.methods/Collecting.methods.htm>

Ministerio de Ambiente y Energia. MINAE. 21 March 2007 <http://www.minae.go.cr/>. Moehlman, P.D. 2002. Equids. Zebras, Assess and Horses. Status Survey and Conservation Action Plan. IUCN/SSC Equid Specialist Group. IUCN, Gland, Switzerland. 21 April, 2007. <http://www.iucn.org/themes/ssc/publications/actionplans.htm#Equids2002>.

Myers, Phil. "Animalia". Animal Diversity Web. 2001. 26 February 2007. <http://animaldiversity.ummz.umich.edu/site/accounts/information/Animalia.html>.

Myers, Phil. "Arachnida". Animal Diversity Web. 2001. 12 April 2007. <http://animaldiversity.ummz.umich.edu/site/accounts/information/Arachnida.html>.

Oboyski, Peter T. "Insect Collection Methods." December 2006. Peter T. Oboyski. 18 April 2007. <http://nature.berkeley.edu/~poboyski/download/collecting.htm>.

"Oonopidae." American Museum of Natural History. 2006. Febrary 26, 2007 <http://research.amnh.org/oonopidae/>.

"pedipalp." The American Heritage® Dictionary of the English Language, Fourth Edition. Houghton Mifflin Company, 2004. 21 Mar. 2007 <http://dictionary.reference.com/browse/pedipalp>.

Petrunkevitch, A. 1960. Arachnida. P42-P162 in Moore, R.C. (ed.) Treatise on Invertebrate Paleontology. Part P: Arthropoda 2: Chelicerata. Geological Society of America and University of Kansas Press, Lawrence, Kansas. 21 March 2007. <http://www.ucmp.berkeley.edu/arthropoda/arachnida/araneae.html>.

Pherotech. Lindgren Funnel Trap. 2007. Pherotech International Inc. 18 April 2007. <http://www.pherotech.com/page182.htm>.

Platnick, Norman. World Spider Catalog v. 7.5. 2007. The American Museum of Natural History. 21 March 2007. <http://research.amnh.org/entomology/spiders/catalog/INTRO3.html>.

Pollack, Amanda. Collecting Tray with Forceps. 18 April 2007

"Rainforest Facts." Raintree. 1996. Raintree Nutrition Inc. 25 April 2007. <http://www.rain-tree.com/facts.htm>.

Resources Inventory Committee. “Inventory Methods for Terrestrial Arthropods Standards for Components of British Columbia’s Biodiversity No. 40.” Resources Information Standards Committee 2.0. 19 October 1998. Province of British Columbia Ministry of Environment, Lands and Parks Resources Inventory Branch for the Terrestrial Ecosystems Task Force. 17 April 2007. <http://ilmbwww.gov.bc.ca/risc/pubs/tebiodiv/terranth/index.htm>.

“Scientific Facts on Ecosystem Change”. 08-Jan-2007. Greenfacts. 18 February 2007 <http://www.greenfacts.org/ecosystems/millennium-assessment-2/2-ecosystem-services.htm#0>.

"Services." National Biodiversity Institute. 2007. INBio. 21 April 2007. </www.inbio.ac.cr/en/serv/serv_asesorias.htm#>.

"species: estimated number of known living species." Online . Encyclopædia Britannica Online. 18 Apr. 2007 <http://www.britannica.com/eb/art-4>.

“Spiders – clasifying spiders”. Australian Museum Online. 2002. Australian Museum. 20 March 2007. <http://www.amonline.net.au/spiders/diversity/classifying/index.htm>.

"taxonomist." WordNet® 3.0. Princeton University. 18 Apr. 2007. <http://dictionary.reference.com/browse/taxonomist>.

"Toward a Sustainable INBio." INBio. 2002

Ulate, William. Personal Interview. 27 April 2007.

Ugalde, Jesús A. and Randall García. *The Essence of the Institution*. Costa Rica: INBio Editorial, 2002.

"U.S. National Park Service: Frequently Asked Questions." nps.gov. 2005. National Park Service. 9 April 2007. <http://www.nps.gov/faqs.htm>

U.S. Department of State. "Overview of Ecotourism in the United States of America." World Ecotourism Summit. May 2002. Department of State. 12 April 2007. <http://www.state.gov/g/oes/rls/or/19412.htm>

Van de Putte, Bert and Randall Garcia. "Toward Sustainability: Experiences of the Instituto National de Biodiversidad, Costa Rica." INBio. December 2004.

Van Tassell, Darin H. and S. Kate Daniel. "The Paradox of Ecotourism in Costa Rica: Can Economic Development and Environmental Preservation Co-Exist?" Delaware Review of Latin American Studies. Vol. 7 No. 2. 30 December 2006.

Viquez, Carlos. Personal Interview. March and April 2007.

Westbroek, Glen. "Examples of Each of the Five Kingdoms." Unlocking the Mysteries: Kingdoms. 15 June 2000. Utah State Office of Education. 26 March 2007. <http://www.usoe.k12.ut.us/curr/science/sciber00/7th/classify/sciber/5king2.htm>

Wood, Monty. Personal Interview. 22 March 2007.

World Conservation Monitoring Centre of the United Nations Environment Programme (UNEP-WCMC). 2004. Species Data (unpublished, September 2004). 20 March 2007 <http://rainforests.mongabay.com/03highest_biodiversity.htm>.