Obtaining Economic Benefits from Sustainably Managed Ecosystems Through Bioprospecting

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Abstract

Bioprospecting has frequently been cited as a sustainable use of biodiversity. Nevertheless in tropical, biodiversity-rich regions the level of bioprospecting falls below its potential, with the result that bioprospecting has had limited economic impacts. We present a bioprospecting program that, in addition to drug discovery, provides economic benefits to and promotes conservation in Panama through the sustainable use of biodiversity. The program was initiated using insights from 20 years of non-applied, ecological research to enhance the likelihood of finding treatments for human disease. Instead of sending samples abroad, most of the research is carried out in Panamanian laboratories. Panama has received immediate benefits for the use of its biodiversity in the form of research funding derived from sources outside of Panama, training for young Panamanian scientists, and enhancing laboratories. Over the long term, discoveries derived from bioprospecting may help to establish research-based industries.

Keywords: biodiversity conservation, benefit sharing, Convention on Biological Diversity, ecological economics, ecosystem services, genetic resources, sustainable development

Introduction

How can developing countries of the tropics that harbor a large fraction of the world's biodiversity obtain benefits from this biodiversity? Often termed "use it or lose it", the challenge has been to promote economic development through the sustainable uses of biotic resources in a manner that also enhances conservation. Put simply, the economic valuation of biodiversity should be harnessed in order to justify the conservation of habitat in its natural state. Particularly promising are medicinal and horticultural products, ecosystem services, ecotourism, and bioprospecting, the investigation of biodiversity as a source of useful medicines or genes (ten Kate and Laird 1999).

In 1992-1993 the Convention on Biological Diversity (CBD) recognized that nations have ownership of, and hence the right to control access to, their species ("genetic resources") and mandated equitable sharing of the benefits derived from biodiversity (Gollin 1993). More recent international agreements have provided additional support for the concept that countries own their species, one that researchers and industry presently abide by (Gollin 1999). Less appreciated is that the CBD clearly indicates that both developing and developed countries should facilitate research on the uses of biodiversity. In this paper we argue that in order to derive benefits from the use of biodiversity, developing countries must strike a balance between these two aspects of the CBD.

Since the drafting of the CBD, the concept that countries own their species has been the primary focus of attention. Many of the academic studies and international conferences have dealt with legal issues such as defining prior informed consent for the use of traditional knowledge and specifying the nature of benefit sharing arrangements (CBD 2006). This resulted from the many cases, some recent, of the use of biodiversity without recompense, including an insecticide from the Indian tree *Azadirachta indica* that has low toxicity to vertebrates (neem), an appetite suppressant from *Hoodia* spp. traditionally used by the bushmen and a heat-stable enzyme from *Thermus aquaticus* that is a key research tool. As a consequence, many governments have developed unrealistic expectations of the value of biodiversity; these have inhibited both basic and commercially oriented research on biodiversity (Gomez-Pompa 2004, Grajal 1999). For example, some countries have passed legislation that severely restricts basic research, such as the export of herbarium specimens as well as research by their own scientists on their own biodiversity (ten Kate and Laird 1999, p19, Grajal 1999). Although difficult to quantify, it seems certain that biodiversity-based research carried out by pharmaceutical and agricultural companies also has been inhibited. This phenomenon resulted from the perception in the developing world that biotic resources have a high value, even in a "raw", unstudied state. In part these perceptions arose because in 1991, a 1.1 million dollar agreement between Merck and Costa Rica's National Biodiversity Institute (Aldhous 1991) fueled unrealistic expectations of substantial access payments or royalties to biodiversity-rich nations.

Better progress depends on a view of bioprospecting that neither dwells on past problems nor assumes that biodiversity must be a source of wealth. In fact, the original intent of the CBD was to develop such a vision. Many expected that the provisions in the CBD that emphasize studies on the use of biodiversity would promote research, including bioprospecting, that would allow nations to capture the value of their natural resources. For example, the CBD indicates that countries should provide for appropriate access to biodiversity (Article 15) and that the developed countries should transfer technology (Article 16). The CBD is a wide-ranging and visionary document that stated that nations should “endeavour to create conditions to facilitate access to genetic resources for environmentally sound uses” as well as “develop and carry out scientific research based on genetic resources”.

In most bioprospecting arrangements prior to 1990 the source country, with expectation of receiving royalties or milestone payments, provided biological materials and the developed country provided research. However, with a success rate of much less than one in 10,000 samples, access payments or royalties are a highly unlikely outcome (McChesney 1996). Additionally, in the case of royalties, the time frame is long, perhaps 10-12 years from discovery to receiving benefits. Even were such payments made, they would fail to meet the goal of economic growth unless they supported effective in-country research on the beneficial uses of biodiversity. This model clearly provides few to no benefits for the source country.

The only practical mechanism by which bioprospecting can provide benefits is by basing as much of the research as possible in laboratories in the source country. The benefits from research include jobs, training, investment in infrastructure and the likelihood that scientific discoveries will lead to additional investment in research and development. For areas with high biological diversity such as the tropics, bioprospecting research could promote substantial economic growth. Despite considerable potential, the benefits for developing countries that are derived from bioprospecting are much below the capacity. One reason is that developing countries have focused on legal considerations that constrain bioprospecting research, including research at the very initial stages. Because crude biodiversity has very low value, research should be facilitated in order to permit countries to realize the actual value of their biodiversity. Nevertheless, inadequate attention has been paid to promoting and streamlining scientific research on the uses of biodiversity.

Since the value of biotic resources can be realized only through research, the low investment in research, has not only failed to keep pace with the need to demonstrate the value of biodiversity, but in particular has resulted in lost economic opportunities. How can we return to the vision outlined in the CBD in which economic value is realized through the discovery of new uses of biodiversity?

Even though the idea that basing research in the source country should be the focus of benefits has been suggested in recent years (Laird and ten Kate 2002), this approach to bioprospecting is in its infancy. In fact, within the biodiversity-rich countries of the world, no programs attempt to link the study of the uses of biotic resources with conservation and scientific and economic development. This has made less compelling the argument that we conserve nature as a means of economic development as well as a future source of medicines and genes.

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What type of economic development might bioprospecting provide?

Recent studies clearly show that nature is still a productive source of new medicines (Koehn and Carter 2005, Newman et al. 2003). A key function of bioprospecting is to provide some of the thousands of compounds that are discovered annually which have interesting structures or activities. A subset of these becomes new "lead compounds", i.e. compounds that are promising enough to merit substantial investment in continued investigation. In a typical year, relatively few lead compounds become approved medicines. Hence, the drug discovery process can be thought of as a pyramid having a very broad base that is composed of thousands of compounds with new activities, with many of these derived from bioprospecting (McChesney 1996). The essential, beginning steps of the drug discovery process provide employment, research opportunities to academic investigators and, in the long run, investment in start-up biotech companies.

At a minimum, developing countries should expect bioprospecting to provide new jobs and economic growth, although additional benefits should be anticipated. In fact the expected benefits are exactly the same benefits that developed countries receive from similar research initiatives, including improved scientific, technical and policy-making capacity, as well as contributions to resource management, tourism and conservation (see Box). A vigorous and productive bioprospecting program will also provide developing country researchers with intellectual property, that is inventions or discoveries derived from research that have potential economic value, such as novel, active compounds or genes. In principle such intellectual property, just as in the developed world, could result in the creation of new industry.

A number of observations indicate that this expectation is quite reasonable. Research-driven industries, with the goal of reducing costs, are increasingly reliant on outsourcing research and development to small firms that have excellence in a particular field of research (Jankowski 2001). Increasingly, small R&D companies that are commercially funded are based in the developing world. According to the World Investment Report (UNCTAD 2005, p. v.), "The traditional view, of more complex production activities being undertaken in the North and simpler ones in the South, is less and less a true reflection of the reality". In fact, between 1996 and 2002, R&D investments from transnational corporations to affiliates based in the developing world increased from 2% to 18% of total investment (UNCTAD 2005, p. xxvi).

With respect to pharmaceuticals and biotechnology, about 17% of R&D worldwide (UNCTAD 2005, p119-121), are expended by these industries. For example, annual spending by the largest pharmaceutical companies on research is estimated at 27-43 billion dollars worldwide (Agnew 2000). Additional research funds are expended by government (National Institutes of Health), non-profit institutions (Howard Hughes Foundation, Medicines for Malaria Venture, Institute for OneWorld Health) and many small companies (Morel et al. 2005). In fact it has been estimated that a third of the new drugs, and perhaps more, including many of the most innovative medicines, are derived from research in academia, the government or small biotech companies (Angell 2004).

Do developing countries have the capacity, in the near term, to carry out the required biodiversity-based R&D? About one third of total research effort in the large pharmaceutical companies encompasses research similar to the initial steps of bioprospecting (ten Kate and Laird 1999). These include the discovery of active compounds through bioassay, purification and structure elucidation, their modification to enhance activity and their testing in vertebrate models. These all are currently employed in our program in Panama and can be carried out in most developing countries. Hence bioprospecting research conducted in academia or in small companies based in the developing world could provide both jobs and promising lead compounds.

Even though the pharmaceutical industry is one of the most internationalized (UNCTAD 2005, p125), tropical, biodiversity-rich countries, aside from Malaysia, have received little investment. Hence the potential economic benefits to be derived from high technology bioprospecting research conducted in academia or in small companies within the developing world greatly exceed the present reality. We envision that economic development derived from bioprospecting can grow in a two-stage process. Initially, substantial research effort must be made in order to generate intellectual property that would have value at an international level. Benefits would accrue in the form of funds that enter the country. In the second stage new companies may be created that are focused on continued R&D of their own discoveries. Even within such research-driven companies, the probability of getting a product to market is slim and the principal economic benefit derives from the research process. For example, the typical investment in a single foreign R&D company exceeds 20 million dollars per year (UNCTAD 2005, p124). Hence, the magnitude of investments is such that the substantial benefits can be obtained from participation in the various stages of pre-clinical research, even without having a product make it to market.

Bioprospecting is primarily a high technology, laboratory-based activity, with most of the benefits accruing to the urban areas. Urbanites are an increasingly important fraction of the population in developing countries, with an increase in Latin America and the Caribbean, for example, from 42% in 1950 to an estimated 85% in 2030 (United Nations 2003, Aide and Grau 2004). Therefore, in addition to demonstrating that intact ecosystems have value, it will be imperative to resolve the conflict, as perceived by urban citizens, the private sector and government, between conservation and the use of natural resources for development. One of the more remarkable characteristics of bioprospecting is that issues of great importance that are often at odds, conservation, sustainable economic development and human health, become interconnected and mutually beneficial.

Scientific studies, technology transfer, infrastructure development and training carried out by the ICBG and its collaborators in Panama

<u>Overview</u>: In order to create a bioprospecting program in which the source country receives immediate and tangible benefits, in 1995 we initiated a collaborative project based in Panama in which most of the drug discovery research is carried out in-country (Kursar et al. 1999). This was based on an imaginative and ambitious program created in 1992 when the National Institutes of Health, the National Science Foundation and the Department of Agriculture of the United States initiated The International Cooperative Biodiversity Groups (ICBG) program (John E. Fogarty International Center 2006). The goals of the ICBG are to combine drug discovery from biodiversity with biodiversity conservation, scientific capacity-building and economic development (Rosenthal et al. 1999). In many regions of the world the future development of biodiversity-based research is threatened by biodiversity losses, restraints on access to biodiversity and weak scientific infrastructure. To address these issues an experimental

approach was applied to the creation of new modes of studying the uses of biodiversity. The ICBG program is based upon "biodiscovery partnerships" in which systematists, chemists, cell biologists, conservationists and lawyers from academia, business and government in the US and in developing countries have succeeded in promoting biodiversity-based research by developing novel institutional and legal arrangements.

In the Panama ICBG agreements with the Panamanian government assure Panama of receiving benefits, such as royalties. However, royalties are not the focus of the project. The emphasis of the Panama ICBG has been to assure that Panama receives immediate benefits from bioprospecting.

The Panama ICBG is based at the Smithsonian Tropical Research Institute (STRI), the University of Panama, and the Institute of Advanced Scientific Investigations and High Technology Services or INDICASAT, all in Panama City, and works closely with Panama's biodiversity agency, Autoridad Nacional del Ambiente (ANAM) as well as with several US universities. The sophisticated infrastructure provided by STRI has allowed us to focus on meeting the project goals of technology transfer and training in Panamanian laboratories. Using ICBG funds, two laboratories were set up in Panama and several existing laboratories in Panama were enhanced. The project also acquired the first nuclear magnetic resonance facility in Panama (Bruker Avance 300MHz). This infrastructure and technical capacity has supported the isolation and structure elucidation by scientists in Panama of over 100 compounds with medicinally relevant activities, primarily from plants. These represent a large fraction of the published studies of the uses of Panama's biodiversity in which all or nearly all of the research had been accomplished in Panama-based laboratories.

Because bioprospecting requires the free exchange of samples and information among systematists, cell biologists and natural products chemists, progress can only be made through collaboration. Hence the project is highly interactive, including in the past and current form five departments at the University of Panama, two laboratories at INDICASAT, STRI and numerous universities in the USA. For example, the laboratory of Dr. Luis Cubilla (Chemistry, University of Panama) joined the ICBG program in 2000 and has isolated over 50 compounds many of which are novel or active against Chagas' disease and leishmaniasis (e. g. Cherigo et al. 2005, Correa et al. 2006, Mendoza et al. 2004). The ICBG has provided training for many young Panamanian scientists. For example, since 2000, Dr. Cubilla's chemistry program has supported the thesis research of 12 undergraduate students and employed 10 assistants. Among these, two are presently studying for Masters degrees, two for Ph.D.s in Mexico and Spain, and one is a postdoctoral fellow in the US.

At INDICASAT innovative assays that do not depend upon radioactivity have been developed for leishmaniasis (Williams et al. 2003), trypanosomiasis, dengue and malaria. The anti-malaria assay, which takes advantage of the absence of a nucleus and DNA in the red blood cell within which the parasite lives, detects *Plasmodium* growth using a DNA-sensitive fluorescent probe (Corbett et al. 2004). The assay has been patented (Ortega-Barría et al. 2005) and scientists from Bolivia, Madagascar and Peru have traveled to Panama to learn the method. Laboratories at the University of Panama as well as those in Puerto Rico and Spain have used this assay to evaluate the activity of new natural products (e.g. Gutiérrez et al. 2005, Wei et al. 2004). Drs. Luis Cubilla and Luz Romero have submitted a patent application for aporphine alkaloids from young leaves of two species of *Guatteria* (Annonaceae) that show exceptional *in vitro* activity against *Leishmania mexicana* (leishmaniasis; Montenegro et al. 2003). These have up to 65-fold higher toxicity towards *L. mexicana* than towards human macrophages (the host cell of *L. mexicana*). Because this suggests that the *Guatteria* alkaloids hold therapeutic promise, these have been patented (Rios et al. 2004).

The conclusion that can be drawn from the above description is that, relative to total funding of about $600,000 per year, the ICBG has provided substantial benefits to Panama, including unique opportunities for Ph.D.-level Panamanian lab leaders and their students to investigate the uses of their own biodiversity, training for many young scientists and improved infrastructure. The technology transfer and training with the Panama ICBG has been recognized within Panama and also internationally as a model program (Dalton 2004, *The Economist* 2005).

What are the obstacles and opportunities for realizing economic and scientific development through bioprospecting?

In developed countries, alliances and collaborations between the large pharmaceutical companies, small R&D companies and academia have considerable economic importance. To what extent has bioprospecting in developing countries followed this model and promoted growth in their economies? The recent, considerable investment in R&D in the developing world has not included bioprospecting, and the extension of the developed-country model to bioprospecting in biodiversity-rich countries has been slow. In other words, developing country scientists have not participated in the more advanced stages of bioprospecting research and few, if any, researchers have used biodiversity-based intellectual property in order to attract funding and establish biotechnology companies in developing countries. Serious barriers remain to be overcome in order to realize economic and scientific development through bioprospecting. Obstacles include restrictive regulations and underdeveloped institutional and scientific capacity.

<u>Legal constraints</u>:

Collaborations are essential for research but can be difficult due to the need for legal agreements with academic and industrial collaborators. In the case of the Panama ICBG, the initial agreement between STRI and ANAM required about three years of negotiations. These long negotiations were due to inexperience on all sides. Subsequent legal arrangements between STRI and collaborators in Panama and the US have been established rapidly and represent one of the successes of the Panama bioprospecting project. Because Panama has not embraced restrictive policies, it provides a model for the management of research on biodiversity.

Lack of experience and restrictive regulations, leading to very slow and expensive legal processes, probably block many biopropsecting projects. At present, sufficient experience exists worldwide such that, in principle, developing countries could be provided with legal advice that is consistent with the CBD, protects the interests of all sides and also allows negotiations to be completed rapidly (Public Interest Intellectual Property Advisors 2006, John E. Fogarty International Center 2006). In some developing countries strengthening of intellectual property protection may be required before R&D investments can be realized.

<u>Developing institutional and scientific capacity:</u>

A major barrier for linking bioprospecting to economic development is that laboratories in the developing world may not be internationally competitive. This key step, enhancing in-country scientific training, infrastructure, funding and institutional capacity deserves to be a focus of development efforts (Annan 2003, Holmgren and Schnitzer 2004, Kettler and Modi 2001). Such support would include providing salary, space and funds for setting up laboratories.

For example, the advent of a nuclear magnetic resonance facility in Panama, joined by a second at INDICASAT, has been a key infrastructural development. These instruments have permitted both PhD-level scientists and students to see their projects through to a logical endpoint, something that previously was impossible. These also represent resources for training as well as an attraction for scientists to relocate to Panama. Hence our experience indicates that providing state-of-the-art infrastructure will play a very important role in enhancing research in the developing world.

Attracting established scientists or highly qualified postdoctoral associates from the developed countries is an essential step. In addition to providing space and set-up funds, it is essential to arrange a secure option for such scientists to return to an institution in the US or Europe should they so choose. Once labs are established in-country, they can obtain research funds from outside the country.

In general, funding to developing country researchers should be provided on a competitive basis, with researchers held accountable for the use of funds and productivity evaluated as part of the competitive process. Accountability should be a centerpiece since indiscriminate funding can actually be an impediment to scientific development. This approach also addresses the issue of institutional limitations that exist in some developing countries. Institutions should be expected to work with donors to maintain accountability and productivity.

The rapid and substantial successes of fields such as genetics and cell biology, as well as their ability to attract funding, can be assigned in large part to the premium placed on collaborating and sharing of materials and techniques among competing laboratories (Edwards 2004). Thus bioprospecting will be most competitive where an open, dynamic research environment is created. Nevertheless a barrier to collaboration is the tendency by some to view bioprospecting as a confidential activity. The Panama ICBG places a premium on collaboration, and to the extent possible, maintains open access, welcomes visits by other researchers, and shares materials and techniques. In support of this approach, the legal and regulatory requirements within developing countries should facilitate research collaborations.

<u>Developing bioprospecting as a discipline:</u>

The non-applied areas of biodiversity research, ecology, conservation, systematics, evolution, and related studies, can have valuable spin-offs, as has been the case in Panama. Finding compounds that lead to marketable drugs is a highly unlikely process and our project benefited from non-applied ecological research that was carried out in Panama between 1975-1995 (Kursar and Coley 2003). Although many programs make random collections, we found that using biological insight enhanced discovery (Coley et al. 2003). Investigations of the uses of biodiversity have also contributed to discoveries in fields such as agricultural and veterinarial applications, cosmetics, foods, construction, industrial enzymes, the development of manufacturing processes that are less polluting, bioremediation, biocontrol, nanotechnology and biomimetic materials (Beattie and Ehrlich 2001, Bar-Cohen 2006).

An opportunity in bioprospecting research is provided by the fact that very few of the thousands of active compounds discovered in academic laboratories and published each year are investigated for safety and efficacy in vertebrate models. In effect, the research process ends before the utility of these compounds has been determined. This deficiency is especially critical in the case of tropical diseases for which safe, effective treatments are desperately needed (Gelb and Hol 2002, Trouiller et al. 2001). The fact that much tropical disease research is done in academic laboratories provides ample opportunities for such follow-up studies. By taking this additional step researchers also would establish more substantial intellectual property. Solutions include providing funding for such follow-up studies as well as minimizing legal impediments to collaborations with pharmaceutical companies.

With respect to agriculture, the urgent need for safer pesticides is underappreciated. Most modern, synthetic pesticides are highly toxic and users may be unaware that these pose grave risks to human health (Dinham and Malik 2003; Alavanja et al. 2004). For example, pesticides may have disproportionate impacts upon children (Weiss et al. 2004) and, in some regions, poisonings due to pesticide misuse may cause more deaths than infectious diseases (Eddleston et al. 2002). These observations should motivate developing countries to find less toxic means of controlling crop pests. Research from developing countries will be needed in order to solve these problems and biodiversity is a likely source of such products. Chemicals naturally made by fungi and plants (e.g strobilurin fungicides and spinosyn, an insecticide), organisms with exceedingly high diversity in many developing countries, could result in pesticides or fungicides with low toxicity to non-target organisms.

Bioprospecting should be broadened beyond collections, bioassay and the discovery of novel, active compounds. Active compounds should be investigated for control of biosynthesis, mechanisms of action and efficacy, as well as modified and retested. Such studies would include neurobiology, vertebrate physiology, biochemistry, genetics, anatomy, histochemistry and organic chemistry. Additionally, studies of how chemicals mediate interactions among organisms in natural systems may inform bioprospecting studies. An important unmet need is information about the safety and efficacy of medicinal plants. Because medicinal plants are commonly used in many developing countries, there is considerable need for accurate information about their pharmacology, safety and risks (Lila and Raskin 2005). Even though more reliable information on the utility of medicinal plants would have beneficial impacts on health care in the developing world, this need has received little attention.

Conclusions

Clearly, with appropriate infrastructure, technology transfer and training many developing countries could carry out much exciting, high quality research within laboratories in their own countries. By developing state-of-the-art technical knowledge of their own biodiversity, developing countries can collaborate and negotiate more effectively with colleagues in academia and industry. In our experience, a self-sustaining research capacity can be developed in a relatively short time such that investigators can independently obtain their own funding. Such research provides immediate economic benefits and has the potential to grow into a substantial industry. Because research on the uses of biodiversity in developing countries has been limited by low investment and regulatory constraints, most biodiversity-based innovations are discovered in the less biodiverse, developed regions of the world. Because many of the mechanisms by which biodiversity provides value can only be realized through research, we propose that we return to the vision outlined in the CBD. Policies should be established that facilitate and promote high technology research and local innovation on the uses of biodiversity, especially key infrastructure improvements such as the example given here of the nuclear magnetic resonance facility. Such research, when properly constituted, provides considerable benefits for developing countries and, at the same time, establishes that biodiversity can provide valuable services. Hence in order to promote scientific development, sustainable development and conservation in a manner that is transparent to the public and spreads benefits in a broad, equitable manner, we believe that biodiversity-based research, including bioprospecting, should be vigorously promoted both in-country and at the international level.

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Benefits from in-country bioprospecting funded nationally or internationally

Improving the scientific and technical capacity of the country such as:

- Research capacity: training and funding enhance the capacity to do research in Panama's educational and research institutions.
- Education: research based at universities is widely recognized to enhance education.
- The development of human capital: university students receive research and training opportunities.
- Opportunities for graduate study: research experience, publications and letters of recommendation allow young scientists to compete successfully for international funding and training at the MS and PhD level.
- Advanced research experience for established scientists in Panama.
- Publications: research from Panama's educational and research institutions is published in international journals.
- External funding: Panama's established researchers can obtain funding from outside of the country.
- Repatriation: Some of the many successful Panamanian scientists who are working outside of the country may return to Panama.
- Knowledge of the uses of its biodiversity can permit Panama to collaborate on equal footing with academics and companies from outside the country.
- Sharing of databases: knowledge of biological resources developed in applied programs will benefit researchers in Panama.

Improving policy making, tourism, conservation and economic growth such as:

- External funding: investments in R & D from outside of the country provides jobs without the use of government funds.
- Economic competition: bioprospecting can provide Panama with a competitive edge over other developing countries.
- Support for national policy makers: improved availability of state-of-the-art scientific advice regarding conservation projects and the management of natural resources.
- The novel research perspective derived from bioprospecting may create new economic instruments for managing natural resources.
- Biodiversity knowledge: provide Panama with knowledge of terrestrial and marine organisms at the molecular, organismal and ecosystem level that will be critical for managing resources.
- Extensive experience with bioprospecting within Panama facilitates and increases the sophistication with which Panama can manage such programs.
- Ecotourism: ecoguides knowledgeable about the uses of Panama's biodiversity can provide information of exceptional interest to visitors, greatly enhancing the ecotourism experience.
- Scientists as citizens: investigators from fields that do not have an environmental orientation, such as chemists and microbiologists can contribute to conservation, economic development and the rational use of resources.
- Urban citizens and the commercial sector can perceive the value of biodiversity and can be motivated to support its conservation and the sustainable use.