SCIENCE PLAN & STRATEGYES FOR THE NEXT DECADE

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1 - Introduction

Biological diversity, or biodiversity, is the term given to the variety of life on Earth. It is the combination of life forms and their interactions with one another, and with the physical environment that has made Earth habitable for humans. Ecosystems provide the basic necessities of life, offer protection from natural disasters and disease, and are the foundation for human culture. The Millennium Ecosystem Assessment (2005) — a scientific undertaking involving over 1300 experts working in 95 countries — recently confirmed the overwhelming contributions made by natural ecosystems to human life and well-being. Yet even as we begin to better understand what is at stake, genes, species and habitats are rapidly being lost.

Concern over the loss of biodiversity and the recognition of its important role in supporting human life motivated the creation, in 1992, of the **Convention on Biological Diversity/CBD**, a legally binding global treaty. The Convention encompasses three equally important and complementary objectives: the conservation of biodiversity, the sustainable use of its components, and the fair and equitable sharing of benefits arising out of the utilization of genetic resources. Participation in the Convention is nearly universal, a sign that our global society is well aware of the need to work together to ensure the survival of life on Earth.

The loss of biodiversity constitutes a critical problem for human existence to the extent that biodiversity science is amply recognized as a priority area of scientific research in both the developed and developing world. On the other hand, the chemodiversity associated to biodiversity constitutes one of the most important defense strategies for maintenance of the planet, due to animals, including humans, and most of microorganisms depend directly or indirectly on plants as a source of food. Biodiversity science spans a wide range of basic scientific disciplines ranging from molecular genetics through to systematics, population through to ecosystem ecology and macroecology, as well as integrative research areas such as conservation biology, biocultural conservation, impacts of climate change, complex systems, ecological economics and environmental ethics (Arroyo et al 2009).

2 - A regional overview of biodiversity

The Neotropical region that stretches from southernmost North America through to southernmost South America, thus encompassing most of the Latin American countries, is one of the most diverse biogeographic regions on Earth (Muñoz & Mondini, 2008).

Palaeogeographic evolution of the Neotropical region over more than 100 Ma fostered an increasing compartmentalization and resulted in a marked increase in biome and habitat diversity throughout the Cretaceous, Tertiary and Quaternary. The arrival of humans 14,500 BP, was followed by intensive cultural diversification and mostly non-intensive land use. Up until pre-Colombian times, the physiographic evolution of the Region together with the outstanding cultural diversification of the Amerindians, reflected in hundreds of languages, generally favored the accumulation of biodiversity and related cultural knowledge. A reverse trend was set into motion in post-Colombian time, culminating in today's large-scale agriculture, plantation forestry and increasing urbanization. In 2006 the UN Population Division projected that in 2050 Latin America urban population will exceed the entire population living in the region today (Arroyo et al, 2009). On the other hand the surviving Amerindians are assembled into 400 groups, representing 34 language families and two special language groups (Montenegro & Stephans, 2006) and represent a mere 1.6% of the world's population, and 7% of the total population of Latin America today.

The Neotropical region monopolizes the Planet's biodiversity due to: diversity of biogeographical divisions, diversity of ecosystems, diversity of species, diversity of life forms and functional groups, concentration of endemic organisms, agro-biodiversity associated with cultural diversity.

Some highlights are: six countries of the Neotropical Region fall into the Megadiverse league; 32% of global biodiversity in vascular plants, summing to an estimated 95,000, for a land area constituting 9.6% of total land area worldwide; in South America: 33% of global biodiversity in birds, 32% of anurans, 25% of mammals and 20% of reptiles; two Vavilovian Centers of Origin of Agriculture and Plant Domestication; seven of the 25 Biodiversity Hotspots for Conservation Priority; a recently-discovered Hotspot for bryophytes at the extreme southern end of South America; 22% of global Frontier Forest. Brazil, the largest country in the region, has an estimated 170-210 thousand described species considering all taxonomic groups, but is believed to have around 1.8 million in total, taking into account microorganisms and fungi (Lewinsohn & Prado 2005). If we consider only vascular plants the country holds 13% of the world's flora.

Main threats to biodiversity of the region are deforestation, fire, over-exploitation, the introduction of exotic species, climate change, and pollution. It is particular worrying that: South America suffered the greatest ever-net forest reduction over the years 2000 to 2005; the Brazilian Cerrado is now disappearing at more than twice the rate as the Amazon rainforest, and; rates of deforestation in other Megadiverse countries like Mexico are still very high. Neotropical terrestrial, fresh-water and marine habitat have already received large numbers of exotic species, spanning the taxonomic hierarchy, but our knowledge regarding specific impacts on biodiversity is woefully incomplete.

Climate warming should lead to easier pole ward migration of species in the northern extreme than in the southern part of the Neotropical region, as a result of the fact that the amount of land increases with an increase in latitude north of the tropics, while in the South America south of the equator, the opposite is true. Results of the first modeling studies on the impacts of climate change suggest certain losses of biodiversity, along with complex feedbacks between drivers such as deforestation and climate change, leading to an exacerbation of global warming. However, experimental studies are still few and, overall, biodiversity scientists in Latin America, particularly ecologists, have been slow to rise to the challenge of tackling, large-scale, complex problems through networking and data sharing (Arroyo et al 2009).

As been pointed out by a recent review of ICSU-LAC (Arroyo et al 2009) huge asymmetries with respect to basic knowledge and/or its accessibility characterize marine and freshwater versus terrestrial habitats. A serious problem in general concerns the lack of georeferenced biodiversity data and the willingness of institutions, with some notable exceptions (e.g. CONABIO, INBio, BIOTA/FAPESP), to make data available on online. The study of ecosystems services is hindered by the lack of data on carbon sequestration, nevertheless, economic valuations of some ecosystem services are beginning to appear, and ecotourism and its variants are well developed in the Region. Climate change research at an ecosystem level is hindered by the lack of long-term data sets and the compilation of Regional data sets, although there are some notable exceptions.

Close to 8500 plants and animals in the Neotropical region are considered to have conservation problems by IUCN standards, but this number is concluded to grossly underestimate the real situation. The most threatened groups are amphibians (32% of total) and fishes (24%); however, the vast majority of species catalogued as endangered (67%), are plants. Although 21% of the Neotropical Region land area is protected - the highest percentage contribution for all developing regions of the world, and higher than in the developed countries - distribution modeling and GAP analysis reveals that the present configuration of protected areas is not always optimally located to protect the Region's biodiversity. Moreover there are huge imbalances comparing the protection of wet forest habitats versus dry forest and scrubland habitats, represented, for instance, by the Cerrado, and the protection of terrestrial habitats versus marine habitats (Arroyo et al 2009).

The vast and biologically-rich Neotropical Region presents an outstanding opportunity to develop biodiversity science in many different dimensions. An overview of institutional arrangements and resources for biodiversity research shows that, within the Neotropical Region, there are many institutions devoted, at least in part, to biodiversity science, among which are found several novel institutions of international standard fully devoted to biodiversity research (Arroyo et al 2009).

3 - The BIOTA/FAPESP Program

Within this scenario, in April 1996 the scientific community, working within the large umbrella that encompasses characterization, conservation and sustainable use of the biodiversity, started to work on the profile of a research program aiming at solving these problems. Three years later, in March 1999, the **State of São Paulo Research Foundation/FAPESP** (**http://www.fapesp.br**) launched the **BIOTA/FAPESP Program: The Virtual Institute of Biodiversity** (**http://www.biota.org.br**).

The state of São Paulo, located in the Southeastern region of Brazil, is the most industrialized state of the country, and has a population of over 40 million people. It currently presents urban and industrial development rates comparable to those of Western European countries, such as Spain, Italy, UK, France and Germany. São Paulo has a population of 41.541.191 inhabitants, around 22% of Brazil's population, a demographic density of 135 persons per km^2, three big metropolitan areas, and the most complex urban network of Latin America. São Paulo's GSP is ≈ US$ 450 billions with a *per capita* income of ≈ US$ 10.000,00 per year. Currently, the state has 645 municipalities and the largest transport system of Latin America, with links between highways, railways, airports and waterways, interconnecting all municipalities and cities with other Brazilian States, as well as with the majority of the Mercosul countries. The state accounts for 33,4% of Brazil's GNP and 42% of the total Brazilian exports, 11% of non manufactured products and 42% of industrialized goods. Approximately 92% of São Paulo exports concern industrialized goods – including airplanes (EMBRAER), cars, trucks & buses. The State of São Paulo also contributes with significant part of the Brazilian chemical industry, with net sales of US$ 103.5 billion in 2008, a new record for the country, becoming one of the 10 largest in the world. It is also Brazilian's biggest sugar cane producer (270 million/tons/year), corresponding to 70% of Brazilian's exports (US$ 5,65 billions in 2007) and is expected to increase another 50% in the next five years.

The two major biomes of the state, Atlantic Forest and Cerrado (Savannah), have been reduced to 12% and 2% of their original areas, respectively. With the exception of the coastal mountains (Serra do Mar), which are still covered with large extensions of remnants of native Tropical Rain Forest, inland forest and Cerrado remnants are highly fragmented. Although, forest clearing started in early 1800's, it grew exponentially in the last half century. From 1962 to 1992 the state lost more than 60% of its native Cerrado cover (Governo do Estado de São Paulo, 1993; http://www.biota.org.br/info/Sãopaulo/index).

The relevance of biodiversity conservation in these two biomes, Atlantic Forest and Cerrado, has been recently recognized with their inclusion in the list of "hotspots" (Myers et al 2000). Therefore, it is not surprising that the biodiversity numbers of the State are extremely high, around 8000 species of higher plants, 5500 of algae, more than 2000 of vertebrates, more than 500000 of invertebrates and the number of microorganisms can only be speculated. At least 30% of these species are endemic, what makes even more urgent the development of tools to, simultaneously, increase our knowledge, establish sound conservation policies and learn to use this natural treasure in a sustainable way. However plant and marine collections of these biomes would require much more effort than in the past, due largely to the understanding that the State needs to reap some dividends from the use of their biodiversity. It was also recognized that conservation and economic development efforts really needs to go hand in hand with drug discovery work.

One of the major problems was the fact that information regarding the biological patrimony of the State of São Paulo already available, was fragmented, disperse, of difficult access and, consequently, underused. Besides, as a consequence of the lack of an updated cartographic base, the location of sampling sites, key information, was usually inaccurate. The greatest challenge was to systematize sampling, using GPS to locate the sampling site/area, to develop an integrated databank for storing this information, and to produce accurate and reliable maps for plotting the spatial distribution of species within the State.

3.1 - The creation of the Program

The first problem to be tackled was the development of tools and means to increase connections among researchers and research institutions working with biodiversity. Therefore, a homepage (http://www.biota.org.br **Figure 1**) and a discussion list were the first steps. Through the discussion list we had a long and very fruitful discussion about the importance of making information on biodiversity knowledge available to public access via Internet.

The most important issue from this discussion was concerning copyrights of, for example, a list of birds, or fishes or plants of São Paulo State published only in the Internet. Once this was solved, by tagging to the "on-line" publication a metadata label with the copyright information, we started publishing the available species lists for the State.

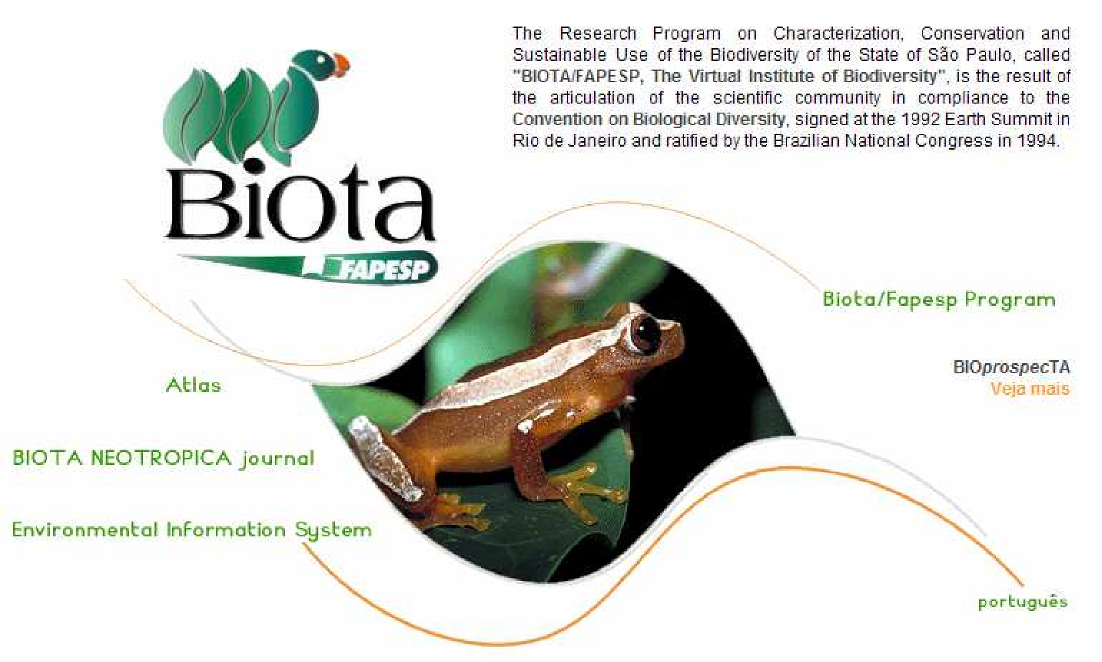


Figure 1 – Homepage of the BIOTA/FAPESP Program, with links to all the major features of the program.

These lists were a starting-point for a thorough inventory of the available knowledge about our native biodiversity. Taking into account that species from São Paulo State (mainly of vertebrates and higher plants) have been recorded, collected and described since early 1800's by European expeditions, we decided that it was important to evaluate the existing knowledge about different taxonomic groups, ranging from virus to mammals and angiosperms, as well as the list of personnel and institutions working with each taxonomic group, and the State *ex situ* and *in-situ* infrastructure for their conservation. At that stage there were approximately 70 researchers involved.

In order to consolidate these inventories and discuss how to start a cooperative effort to study the biodiversity of the State, in July 1997 we organized a Workshop, with over 100 participants from many research areas and institutions. The quality of the documents prepared for that meeting encouraged us to publish them in a series of 7 volumes named *Biodiversity of the State of São Paulo: a synthesis of knowledge at the end of the 20th century (Biodiversidade do Estado de São Paulo: síntese do conhecimento ao final do século XX*) and to make them fully available through the Internet (http://www.biota.org.br/publi) (**Figure 2**) During that meeting we defined as long-term common objective for all the BIOTA/FAPESP research projects, the study of the biodiversity (using the broadest definition of biodiversity as stated in the CBD) of the State of São Paulo aiming:

a) to inventory and characterize the biodiversity of the State of São Paulo, and define the mechanisms for its conservation and sustainable use;

b) to understand the processes that generate and maintain biodiversity, as well as those that can result in its deleterious reduction;

c) to standardize sampling, making the use of GPS mandatory;

d) to make information relevant to conservation and sustainable use of biodiversity available to decision makers;

e) to ensure fast and free public access to this information;

f) to improve teaching standards on subjects related to conservation and sustainable use of biodiversity.

Figure 2 – Copy of the covers from the 7 volumes of the **Biodiversity of the State of São Paulo: synthesis of knowledge at the end of the XX century** series.

The research projects linked to the Program were conducted in order to increase the academic knowledge about the States' biodiversity, and to, simultaneously, produce data potentially useful for improving State policies on biodiversity conservation and sustainable use.

All major public universities (USP, UNICAMP, UNESP, UFSCar, UNIFESP), some private universities (such as PUC, UNAERP, UNITAU, UMC and UNISANTOS), research Institutes (such as the Instituto de Botânica, Instituto Florestal, Instituto Geológico, INPE), EMBRAPA Centers, and NGOs (such as Instituto Socioambiental, Fundação SOS Mata Atlântica, Conservation International and Reference Center on Environmental Information/CRIA) took part in the first ten years of the Program. Considering just researchers linked to those institutions within the State of São Paulo, the BIOTA/FAPESP community brings together approximately 500 PhDs, plus 400 graduate students. In addition there are 100 collaborators from other Brazilian states and approximately 80 from abroad.

An important feature of the BIOTA/FAPESP Program is that the researchers involved are conducting their research on areas of their specific training and skill, but all of them have added common goals to their projects. Furthermore, they are using a set of common tools that have been developed for integrating data within the BIOTA/FAPESP Program.

3.2 - The Environmental Information System/*SinBiota*- http://sinbiota.cria.org.br

The establishment of a standard record form to register sampling data also enhanced connectivity among projects. All research teams discussed this protocol during almost one year, before reaching a final agreement on the mandatory fields. In the end, the following nine mandatory fields were established: sampling author; date; locality, including the geographical coordinates obtained by GPS; municipality; watershed; taxa1; method; ecosystem and Conservation Unit (if applicable). Besides these nine mandatory items, there are more than forty supplementary fields that can be used to give more detailed information, if required, regarding the specific taxonomic group or research.

As the result of a collective effort, these tools (standard sampling form and standard form for species lists) have proved to be suitable to all new research projects and are strongholds of the BIOTA/FAPESP Program. They were also essential to the construction of a databank for registering all samples collected by researchers participating in the Program. All data produced is included in the

Environmental Information System (http://sinbiota.cria.org.br) implemented by the Reference Center on Environmental Information/CRIA (http://www.cria.org.br) in collaboration with the Instituto de Computação (http://www.ic.unicamp.br) of the State University of Campinas/UNICAMP (http://www.unicamp.br) (**Figure 3**). This system uses free computational languages and software, therefore it can be applied for developing similar systems in other states of Brazil or elsewhere, at low cost. During the development of the system major international initiatives, such as Species 2000 (http://www.sp2000.org), were studied and considered, opening possibilities for future integration of the *SinBiota* with these worldwide efforts.

A standard pattern of species lists was established for each major taxonomic group recognized by Margulis & Schwartz, K.V. (1997). Consequently, attached to the metadata of where, who, when and how sampling was carried out, the researcher sends the associate list of taxa collected in that specific locality.

3.3 - Atlas BIOTA/FAPESP - http://sinbiota.cria.org.br/atlas

Along with the development of the database and its interface with Internet, a digital map of the State of São Paulo, in a 1:50.000 scale, was produced in collaboration with the Instituto Florestal (http://www.iflorestsp.br/) and UNICAMP (Instituto de Geociências http://www.ige.unicamp.br ; Faculdade de Engenharia Agricola http://www.agr.unicamp.brand CEPAGRI http://www.cpa.unicamp.br). The map has detailed information about: urban areas; roads; county boundaries; rivers; areas covered by *Eucalyptus* spp and *Pinnus* spp. plantations; Conservation Units; and remnants of native vegetation. The natural vegetation is divided into: primary and secondary Atlantic forests; all three physiognomies of Cerrado (open grassland; grassland with shrubs and trees; predominantly trees and shrubs); riparian forests; floodplain vegetation and coastal vegetation (mangroves and restinga, which is a kind of forest growing on sandy plains of coastal regions seasonally waterlogged by brackish waters). The digital atlas is an assemblage of the 416 cartographic charts from the 1972 IBGE (Instituto Brasileiro de Geografia e Estatística http://www.ibge.gov.br) map of São Paulo State, updated with Landsat 5 or 7 satellite images from 1998/99. (**Figures 4 & 5)**

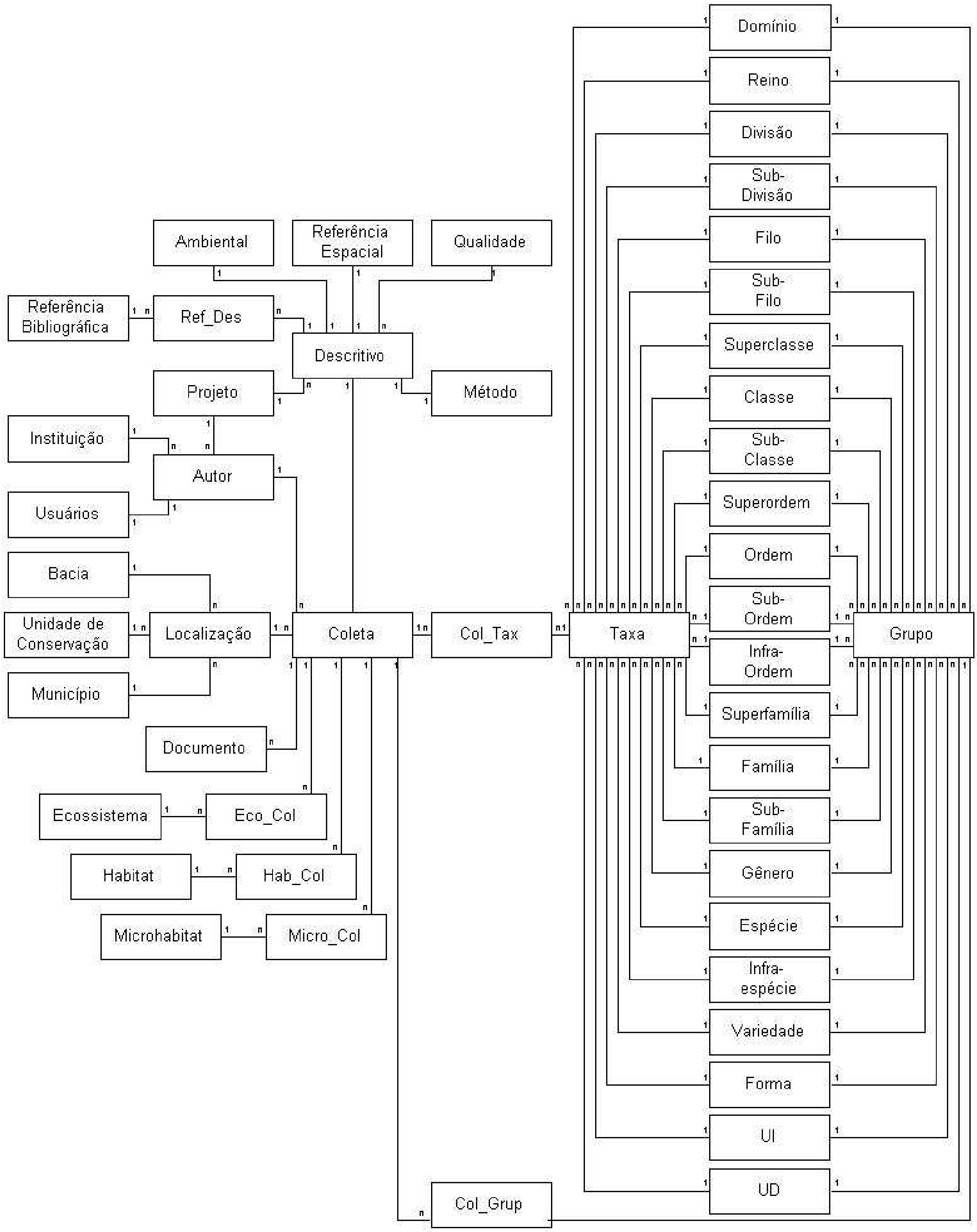


Figure 3 – Layout of the structure of the databank developed for the BIOTA/FAPESP Program.

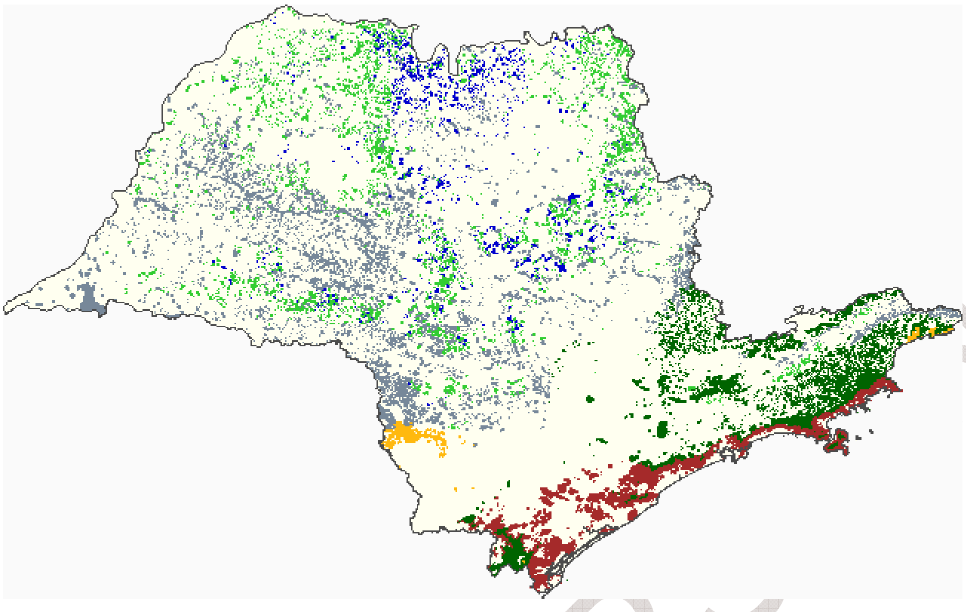


Figure 4 – Map of the remnants of native vegetation of the State of São Paulo. Brown and Dark Green – Ombrophylus Dense Forest; Yellow – *Araucaria* Forest; Grey – Semideciduous Forest; Blue and Light Green – Cerrado.

Figure 5 – Atlas BIOTA/FAPESP – part of the optional layers to be selected for *on the fly* map production.

The geographic coordinates, one of the mandatory fields from the standard sampling form, connect the database to the digital map, allowing, in this stage, a display "on the fly" of the spatial distribution of occurrence sites of species registered in *SinBiota*. The system also allows zooms, besides the connection with the standard sampling form related to the sites plotted on the map, and the visualization of all the registered information concerning that species (**Figure 6**)

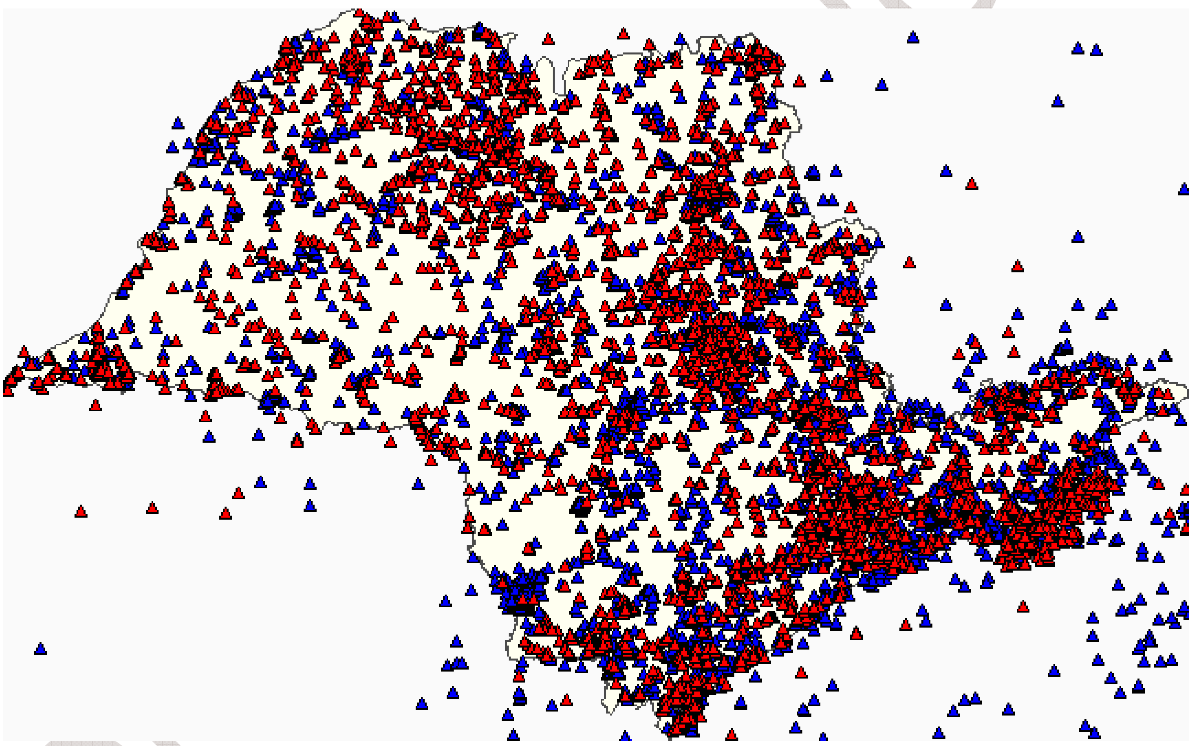


Figure 6 – Sampling effort within the State of São Paulo. In blue samples collected by the BIOTA/FAPESP Program; in red samples deposited in biological collections (Museum & Herbaria)

3.4 - SpeciesLink

Once solved the problem of a standard method to register samples collected within the BIOTA/FAPESP Program, we turned our focus to make available the precious information withhold by Museums, Herbaria, Culture Collections, Arboretums and other biological collections of the State of São

Paulo. With this objective the Program financed the development of the "Distributed Information System for Biological Collections: Integrating Species Analyst and *SinBiota* (FAPESP)", also known as ***speciesLink***. The main goal of the project was to implement a distributed information system to retrieve primary biodiversity data from collections within the state of São Paulo, Brazil, integrated to other networks and to the observation data registered in the SinBiota database. A number of tools were also developed to help collections with data cleaning and to enable ecological niche modeling. The project team aimed at using current advances in databases, distributed systems, communication protocols, connectivity (**Internet 2**) and artificial intelligence, to achieve the following goals:

a) to develop a distributed information system to retrieve biodiversity data from biological collections within São Paulo State, from *SinBiota,* and from collections participating in international information networks;

b) to study and develop mathematical models to predict species' ecological niches and geographical distribution, using data from the distributed information system as input;

c) to develop applications to solve specific problems in biodiversity, such as: invasive species, climate change, endangered species protection, conservation management, using data from the distributed information system and also the modeling tools.

At the start 12 collections of the State of São Paulo were connected, but the project gained momentum once curators of biological collections realized the increase in visibility of their institutions through making their data available to internet, having assured the recognition and the credit of their scientific authority. The fear of loosing identity gave place to a great interest in not only making the effort of digitizing labels, but whenever possible scanning the material and placing also the image in the internet (one excellent example is the digital collections of plant type material that most herbaria around the world made available in the last decade). In the digital era biological collections centuries old gained a new role of paramount importance, as holders of data on species geographical distribution in the past to support biogeographical studies as well as species extinction. As a result of its success further development of the *speciesLink* project was funded by **GBIF** (Global Biodiversity Infrastructure

Facility) and JRS Foundation and today interconnects 159 biological collections from São Paulo State (Instituto de Botânica/IBt, USP, UNICAMP, UNESP, Instituto Agronômico de Campinas/IAC, Instituto Florestal/IF, Instituto Butantan, Instituto Biológico, Instituto Adolfo Lutz, Instituto de Pesquisas Tecnológicas/IPT), from other Brazilian States (including INPA, Rio de Janeiro Botanical Garden, Museu Nacional, FIOCRUZ, EMBRAPA, Federal Universities of CE, ES, PE, PI, PR, RN, SE, PUC Rio Grande do Sul, UE Londrina, UE Maringá), from abroad (New York Botanical Garden, Missouri Botanical Garden, University of California, Pontificia Universidad Católica del Ecuador) as well as other international initiatives (GBIF, OBIS/Ocean Biogeographyc Information System). In total the system holds on line information about 3,000,602 registers, from which 1,362,378 are georeferenced.

3.5 - The BIOTA/FAPESP meetings

In spite of these electronic means of connecting research projects, researcher meetings are of paramount importance. In ten years the BIOTA/FAPESP Program organized six Symposia (http://www.biota.org.br/info/historico), with the participation of project leader/senior researchers along with undergraduate (BSc)/graduate students (MSc and PhD), and pos-docs.

During the year there is at least another general meeting involving project leader/senior researchers, and usually one thematic meeting, for example, bringing together all research teams working with fresh water, from invertebrate to watershed functioning.

Usually, after the Symposium, an evaluation meeting takes place with the participation of four/six members of a Scientific Advisory Committee. At these meetings there are discussions about progresses attained by individual projects and by the Program as a whole. The reports presented by this panel of experts, designated by FAPESP to evaluate the BIOTA/FAPESP Program, are available at http://www.biota.org.br/info/sac/)

3.6 - Biota Neotropica (http://www.biotaneotropica.org.br)

In 2001 the Program launched an open-access electronic peer-reviewed journal the on-line journal BIOTA NEOTROPICA (**Figure 7A**), to publish results of original research, associated or not to the program, concerned with characterization, conservation and sustainable use of biodiversity within the Neotropical region. Papers are submitted within the following categories: articles, inventories, thematic revisions, taxonomic revisions and short communications, in English, Portuguese or Spanish.

In nine years the journal is becaming an international reference in its area, being indexed by The Thomson Scientific Database/ Zoological Record, EBSCO, CAB International, Directory of Open Access/DOAJ as well as by the Scientific Electronic Library Online/SciELO.

Since 2008 the journal is publishing four numbers per year, with an average of 25 papers per number. BIOTA NEOTROPICA's homepage is visited by more the 40.000 users per month (**Figure 7B**).

Figure 7A – Cover of the April-June/2009 volume of Biota Neotropica.

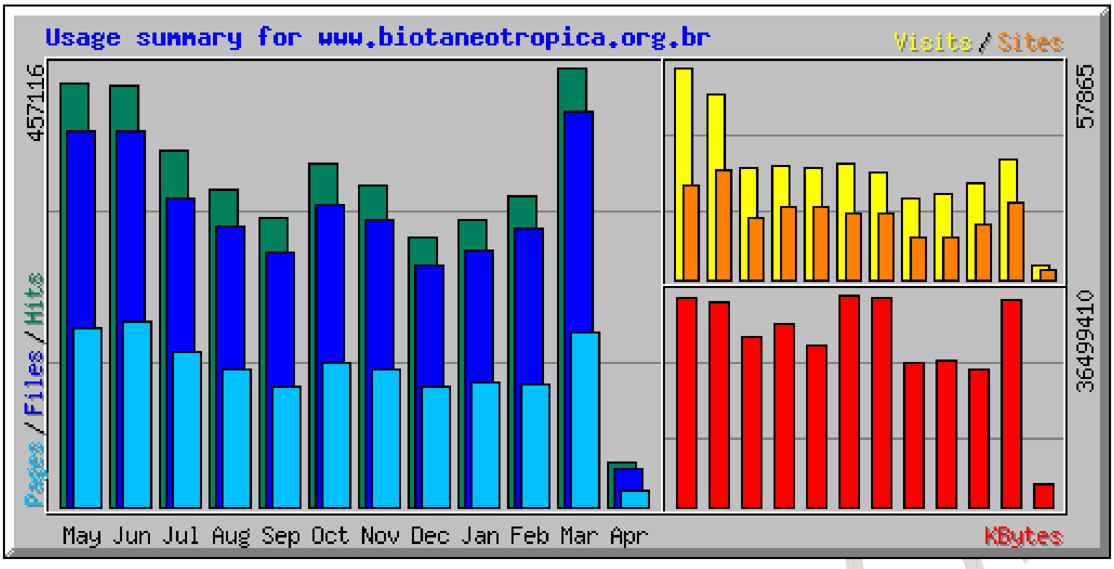


Figure 7B - Monthly summary of access to the homepage of Biota Neotropica.

3.7 - BIO*prospec*TA - São Paulo State Bioprospecting Network (http://www.bioprospecta.org.br)

In 2002 the program began a new venture called BIO*prospec*TA (http://www.bioprospecta.org.br), in order to search for new compounds of economic interest

Natural products as source of novel drugs continue increasing in the western pharmaceutical industry, and in the period of 1970-1980 resulted in a fantastic number of prototype molecules. Of all medicines in the market today, 49% are natural products, semi-synthetic natural product analogues, or synthetic compounds based on natural products pharmacophores, indicating the importance of secondary metabolites in drug discovery. The total drug market in western medicine is about US$ 250 billion per year. Every year about 40 new drugs are introduced into the market, the so called "blockbusters", having profits of about US$ 1-5 billion per year.

In recent years the interest in discovering new targets is growing rapidly, and nature has been reconsidered to be a powerful source of new lead molecules. Thus, bioprospection research, although viewed as long term and high money intake process, remains the only valid approach to obtain large amount of lead molecules through the screening of thousands compounds isolated from plants, and other organisms from our biological resources.

Taking in account this scenario a pilot program for bioprospecting plant species in the State of São Paulo has been pioneered within the initial phase of the BIOTA/FAPESP Program. The success of this first project, demonstrating the viability of this integrated approach, led the BIOTA/FAPESP Program to start a subprogram, BIO*prospec*TA, focusing on screening of the chemical diversity of native microorganisms, plants (higher plants and cryptogams) and animals (invertebrates and vertebrates) both in land and marine, with potential to be economically explored.

This new cooperative venture was envisaged to transform the economic potential value of biodiversity, as source of new lead molecules that can be synthesized by commercial partners of pharmaceutical, cosmetic, food and agrochemical industries, generating royalties to be partially used in biodiversity conservation and restoration infrastructures. So, the results of this cooperative research effort may support a rational use of the State's biodiversity.

In order to establish a competitive bioprospecting program in the State of São Paulo to screen thousands of samples, it was necessary to adapt local expertise to the new needs. It is true that this network would not be able to compete with developed countries in the search for new drugs, especially those related to "developed countries diseases". But the large experience of the research groups of São Paulo State in this area, could allow us to create similar strategies to solve regional problems, especially to combat orphan diseases like leishmaniasis, Chagas, dengue, malaria and other tropical diseases. In addition, the chemical diversity of species from Neotropical forests and savannahs is still a useful source of new potential anticancer, antioxidant, antifungal, anti-inflammatory or antibiotic compounds. Thus, these targets must also be taken into consideration, due to the potential benefits that a new discovery in these areas could bring to the Brazilian economy.

The BIOTA/FAPESP Program has brought together a large group of researchers involved in the taxonomical knowledge of our biodiversity, as well as tools to map the spatial distribution of species within the State. Adding to that, the State of São Paulo had several research groups working on all areas which are important for a successful bioprospection program, with remarkable experience and proved competences, but isolated. So BIO*prospec*TA was a way to promote and improve the integration of these competences within the common goal of achieving not only a sustainable way to use our biodiversity, but also to make it economically profitable, helping to improve our competitiveness in the global economy.

The goal of BIO*prospec*TA was to organize a network of researchers and laboratories with the following objectives:

a) Standardized collection of biological samples (plants, microorganisms, marine species, insects, etc.) and pre-processing of raw materials for the subsequent preparation of extracts;

b) Establishment of a bank of extracts and pure compounds from plants, microorganisms, marine organisms and other natural sources, with the required automation and data management facilities;

c) Establish a flow between complimentary research groups from standardized extracts, fractionation and purification; screening of extracts (ideally High-Throughput Screening using small sample volumes); identification and characterization (NMR, Crystallography, LC/GC-MS, etc…) of promising extracts/compounds; pharmacology and toxicology of promising bioactive extracts/compounds; synthesis of bioactive natural products and their derivatives; medicinal chemistry and drug design applied to the development of promising compounds, whenever possible with private sector partners.

d) Development of new in-vitro and in-vivo bioassays;

e) Development of a database structure for the data processing of the program.

It is important to emphasize that beside the bioprospecting goal, the program focused also on the last advances on natural product chemistry (phytochemistry, molecular biology, and pharmacology).

During the last five yeard BIO*prospec*TA supported 16 projects, that published 180 papers and deposited four patents. Cosmetic and Pharmaceutical companies already showed interest in a partnership to screen BIO*prospec*TA bank of extracts for specific targets.

3.8 - Improving public policies of biodiversity conservation and restoration

During 2006 and 2007 the BIOTA/FAPESP researchers, in collaboration with the State of São Paulo Secretary for Environment/SMA and Conservation International, made an extraordinary effort to synthesize its databank in a set of

8 maps of biodiversity conservation and restoration priority areas in the State of São Paulo. Detailed biological and of landscape metrics information every single area indicated in these maps have been synthesized in the book **Diretrizes para conservação e recuperação da biodiversidade do Estado de São Paulo** (Rodrigues et al 2008)

These maps (**Figure 8**) and the book (**Figure 9**) have just been adopted by the government of the State of São Paulo as the legal framework for biodiversity conservation policies (State Secretary of Environment/SMA Resolutions 04/2008, 15/2008, 85/2008 and Decree 53.939/2009, State Secretary of Agriculture/SAA for licensing sugar cane plantation areas; State Secretary of Justice Normative Act 565/209 PGJ) for impact assessment in the state. It is a rare example of how a large and well planed research effort can be used to set environmental policies of an industrialized State such as São Paulo.

Figure 8 – Map showing at the center the most important areas to be restored with native vegetation, reconnecting isolated remnants to increase their capacity to preserve the States' biodiversity. The smaller map on the top shows areas were new Conservation Units should be established, while the other small map indicates areas of the State of São Paulo were the biological knowledge available is not sufficient to support the definition of priorities to preserve native biodiversity.

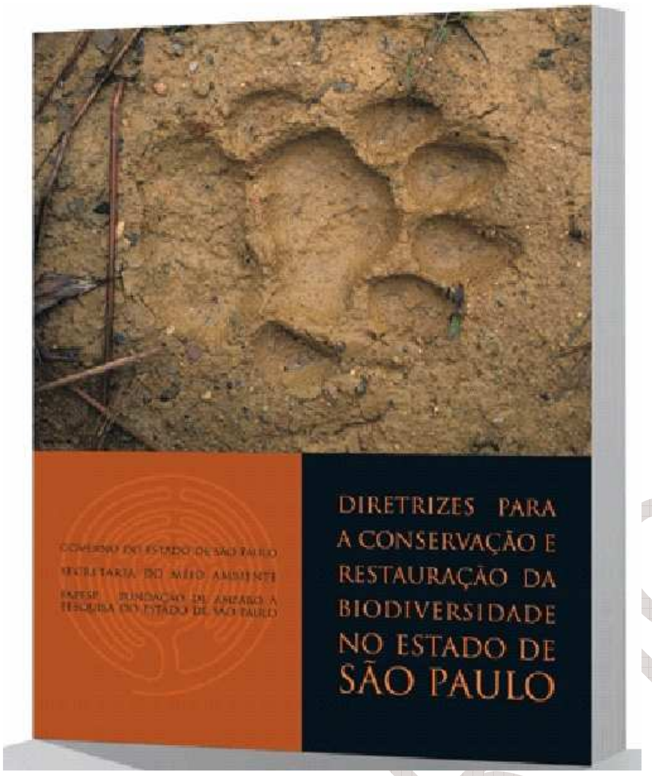


Figure 9 – Cover of the book **Guidelines for biodiversity conservation and restoration in the State of São Paulo** (Rodrigues et al, 2008), that synthesizes the information used to establish the priority areas presented in the maps.

3.9 - Publications & Human resources

In 10 years, with an annual budget of approximately 2 millions USD the BIOTA/FAPESP Program supported 90 major research projects - which trained successfully 172 undergraduate, 169 MSc, 108 PhD students, as well as 79 pos-docs **(Figure 10).** Produced and stored information about approximately 12.000 species and managed to link and make available data from 35 major biological collections of the State of São Paulo. This effort is summarized in more then 600 articles published, in 180 scientific journals from which 110 are indexed by the Institute for Scientific Information (ISI) data base. Among the indexed periodicals, Nature and Science have the highest impact factor, and the median value among all indexed periodicals that authors of the Biota program have published was equal to 1.191, significantly higher then the average for the area in Brazil. Furthermore, the program published, so far, 16 books and 2 Atlas.

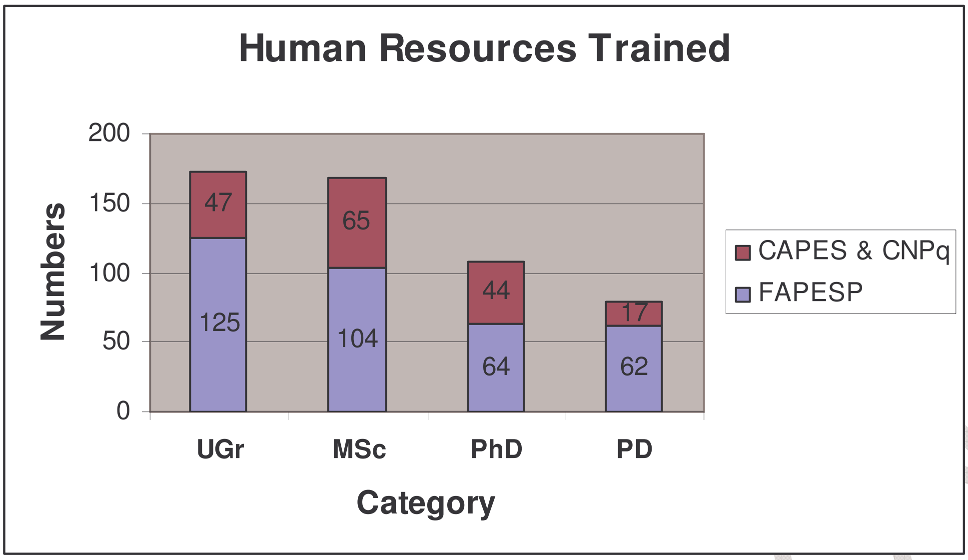


Figure 10 – Undergraduate, MSc, PhD and Pos-Docs students trained by research projects within the BIOTA/FAPESP Program, with scholarships from FAPESP or from the Federal government (CAPES and CNPq).

3.10 - Internet 2

Finally it is important to register that "when establishing an agreement with the National Science Foundation (NSF) in order to enable the access of the whole research system of the State to the Internet 2 network of the US and the rest of the world, FAPESP presented the cooperation between BIOTA and the Species Analyst project of The University of Kansas as an example of interaction that would demand such a communication facility. This is another product of the BIOTA program with immediate benefits to the whole scientific community of São Paulo." (Perez 2002).

4 - Planning the next 10 years

Revisiting the broad objectives of the BIOTA/FAPESP Program we realize that some of them are long lasting and still prevail in similar initiatives around the world, such as DIVERSITAS (http://www.diversitas-international.org/) whose mission is: a) promote an integrative biodiversity science, linking biological, ecological and social disciplines in an effort to produce socially relevant new knowledge; and b) provide the scientific basis for the conservation and sustainable use of biodiversity. Nevertheless, after 10 years, we see the need to modernize methodologies and techniques as well as to bring new scientific challenges to broader the community of scientist potentially interested in joining the BIOTA/FAPESP Program, and to keep producing high standard science. One of the biggest challenges of this new phase is to give the BIOTA/FAPESP Program a position in the international arena that matches the quality of the science we produce.

In June 2009, during two days (3 & 4th of June - **Workshop BIOTA + 10: setting agenda and priorities for 2020**), more than 300 scientists and students associated to research projects within the theme biodiversity characterization, conservation restoration and sustainable use, already linked or not to the BIOTA/FAPESP Program, discussed priorities and an agenda for the next ten years of the Program.

As a result of this discussion, it was decided that the following objectives of the BIOTA/FAPESP Program will be further pursued in the next decade

- To inventory and characterize the biodiversity of the State of São Paulo, by defining the mechanisms for its conservation and sustainable use;
- To understand the processes that generate and maintain biodiversity, as well as those that can result in its deleterious reduction;
- To produce estimates about biodiversity loss in different spatial and time scales.
- To evaluate the effectiveness of conservation initiatives within the Stateof Sao Paulo, identifying priority areas and components for conservation.
- To increase the ability of the State of Sao Paulo and public and private organizations in managing, monitoring and using biodiversity in a sustainable way.

Furthermore, the following **(ten) points** have been thoroughly discussed and elected as top priorities for the next ten years.

4.1 – Including native biodiversity restoration as one main objective of the BIOTA/FAPESP Program

A second major challenge is to incorporate native ecosystem restoration, mainly focusing in the results of the BIOTA/FAPESP Program synthesized in the book **Guidelines for biodiversity conservation and restoration in the State of São Paulo** (Figure 9) and the set of maps with the priority areas for biodiversity conservation and restoration in the State of Sao Paulo.

The need to implement a biodiversity restoration program in the State of Sao Paulo is so urgent, that it justifies changing the name of the BIOTA/FAPESP Program to "Research Program on Biodiversity characterization, conservation, **restoration** and sustainable use".

Biodiversity restoration program should focus on reconnecting isolated fragments of native vegetation, mainly Semideciduous Forest and Cerrado areas, to increase their carrying capacity and contribute to the reestablishment of the State's capacity to maintain viable populations of the large mammals of these phytophysiognomies, like the Giant Ant Eater [*Myrmecophaga tridactyla* (Linnaeus, 1758), Myrmecophagidae], the Maned Wolf [*Chrysocyon brachyurus* (Illiger, 1815), Canidae], the Pampas deer [*Ozotoceros bezoarticus* (Linnaeus, 1758), Cervidae], some wild cats [Puma *Puma concolor* (Linnaeus, 1771); Oncelot *Leopardus pardalis* (Linnaeus, 1758) and Margay *Leopardus wedii* (Schinz, 1821), all Felidae], some monkeys [Black-faced lion tamarin *Leontopithecus caissara* (Lorini & Persson, 1990), Callitrichidae; Black howler monkey *Alouatta caraya* (Humboldt, 1812), Cebidae] and the Giant Armadillo [*Priodontes maximus* (Kerr, 1792), Dasypodidae].

In order to increase adherence to the program by land owners the restoration program here proposed should use the legal framework established by the Brazilian Forestry Code (first published in 1965, altered in 1989 and altered again by MP 1956-50 in May 2000) in relation to Permanent Preservation Areas along river margins and the mandatory preservation of 20%

of native vegetation, defined as Legal Reserve in the 1965 code, and reinforced in all later changes of this law.

Native vegetation restoration procedures are well established in the State of Sao Paulo, and the SMA 8 (published in 7 of March, 2007) Resolution of the State Secretary of Environment brings the list of more then 239 native arboreal species that must be used, as well as the precautions required to keep genetic diversity in these replanted forests. The State Decreed 53.939 (published in 6 of January, 2009), based on the priority areas maps produced by the BIOTA/FAPESP Program, reinforces the obligation to have the Legal Reserve Area within the watershed were the rural property is legally registered. The law allows a group of properties to have their Legal Reserve Area all together in a sort of condominium, a practice that brings a significant increase in the biodiversity conservation value of these areas and therefore should be promoted. Nevertheless to keep regional biodiversity standards, it is of paramount importance to have Legal Reserve Areas spread across the State instead of having them all concentrated in two or three watershed where the proportion of preserved areas is already higher.

Initiatives like the **Pacto pela Mata Atlântica** (http://www.pactomataatlantica.org.br), will be fully supported by the BIOTA/FAPESP Program and whenever possible, and of mutual interest, the Program will generate data for actions aiming to increase connectivity among fragments and biodiversity conservation value of Atlantic forest remnants. On the other hand the Program should foster and promote research to support the development of our capacity to restore other ecosystems like Cerrado, knowledge extremely important for 18 of the 22 UGRH (Units of Water Resources Management) of the State, and Restinga (seasonally flooded Coastal Plain forest or scrub).

It is also important to foster and promote research on breeding and reintroducing native fauna in restored fragments of native vegetation, as well as in some protected areas, were hunting and poaching reduced native populations with large impact in vital ecological processes like seed dispersion (Jordano et al, 2006). In contrast with arboreal species of Atlantic Forest, for which three decades of research lead to consolidate protocols for native forest restoration, mainly inland Gallery Forest and its adjacent Semideciduos Forest

(Rodrigues & Leitão Filho 2004), when it comes to fauna our current knowledge is extremely limited.

4.2 – Development and implementation of a new information system for the BIOTA/FAPESP Program

Considering that the actual Environmental Information System used by the BIOTA/FAPESP Program, that comprises two central components: ***SinBiota*** (http://sinbiota.cria.org.br), shown in Figure 3 and the **BIOTA/FAPESP Atlas** (http://sinbiota.cria.org.br/atlas), shown in Figure 4 and 5, was developed 10 years ago, there is an obvious need to design and implement a new system.

Ten years ago **SinBiota** was the state of art in information systems for biodiversity, being the first to handle data for all recognized taxonomic groups of Prokaryotes and Eukaryotes, from terrestrial, marine and fresh water ecosystems, connecting sampling data with a 1:50.000 map of the State of São Paulo with remnants of native vegetation, as well as rivers & dams, cities, roads and Conservation Units (**Figure 11**). Therefore it was used as a model for the development of worldwide initiative like the Global Biodiversity Information Facility/GBIF (http://www.gbif.org).

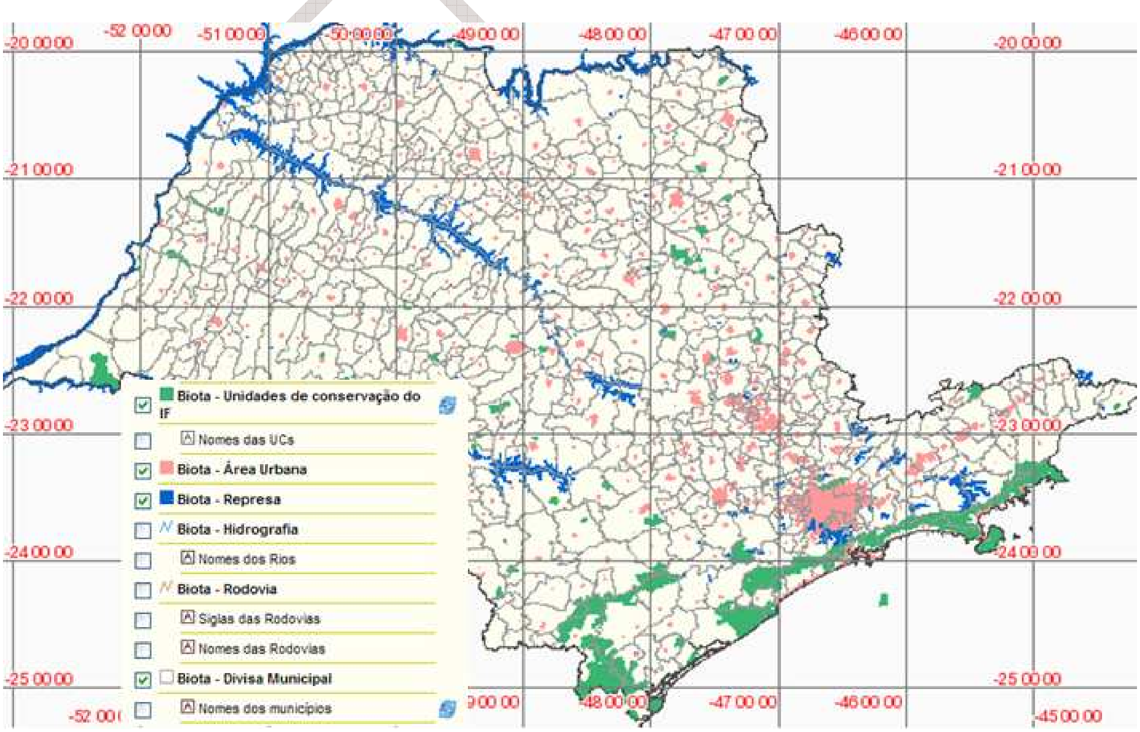


Figure 11 – Some layers of the updated map of the State of São Paulo produced by the BIOTA/FAPESP Program and used in connection with the Environmental Information System/SinBiota of the Program.

BIOTA + 10 workshop participants were unanimous in pointing SinBiota as one of the major achievements of the BIOTA/FAPESP Program, but were also unanimous in proposing the following changes in the system: a) expand the cartographic base of the system to the natural limits of the major biomes of the State of São Paulo, Atlantic Forest *lato senso* (Joly et al, 1999) and Cerrado *lato senso* (Oliveira & Marquis, 2002), as well as the natural limits of watersheds; b) a built in mechanism of data auditory to avoid mistakes such as misspelling species names and/or geographic coordinates the occurrence of sampled species; c) built in tools to allow exporting and importing data from species distribution models (SDM) and ecological niche modeling (ENM) (Elith & Graham 2009) like Genetic Algorithm for Rule-set Prediction/GARP, Maximum Entropy/MaxEnt, Geographic Information System for Biodiversity Research/DIVA-GIS, Support Vector Machine/SVM, Ecological Niche Factor Analysis/ENFA, and novel methods that are being developed (Elith et al 2006); d) increase the portability of the system, to allow its replication in other States, Regions and Countries interested in hosting their own databank and maps; e) standardize all fields and procedures to ensure full interoperability with international initiatives like Global Biodiversity Information Facility/GBIF (http://www.gbif.org).

The new version of the information system (**SinBIOTA 2.0**) should be developed following two distinct stages:

1) Writing a Reference Document specifying in detail the Environmental Information System used today and compare it with similar initiatives around the word as well as the state of art in this area of Computational Sciences;
2) Incremental implementation of modules, following the Reference Document in permanent contact with users, to keep the new system as close as possible of their needs.

In stage 1 we will need to prepare a Reference Document were the functional characteristics of the new system, as well as it's interoperability with other systems and it's portability, are defined by experts in biodiversity characterization, conservation, restoration and sustainable use developing research projects within the BIOTA/FAPESP Program. The preparation of this document requires two types of knowledge: **(i)** the state of art of biodiversity information systems with similar size and purpose, which managed to identify solutions to fill the operational and functional gaps of the ***SinBiota;*** **(ii)** detailed knowledge of the requirements of the users, such as: data quality criteria/standard; metadata accuracy; data cleaning tools; modeling tools. One possible source of inspiration of the new SinBiota are the tools developed by **The Atlas of Living Australia (www.ala.org.au/).**

The next stage (2) requires update knowledge of Software Engineering to establish the steps of implementation, the documentation protocol to be used, the profile of the development team, the tests to be performed and the methodology for monitoring implementation and validation. Requires, also, experience with applications for large distributed databases, which uses Web to interconnect and to have data uploaded. The team responsible for this second document must be familiar with the types of data handled in the BIOTA/FAPESP Program, in particular aspects of sampling, georeferencing and storing specimens in biological collections; inclusion of new layers of data (from DNA Barcoding to demographic and socio-economic data); development of interface with systems like Google maps and climate change scenarios,

To be able to answer questions like: What is this organism? What does it eat? Does it carry disease? How can it be controlled? We need a) names and classification; b) identification keys; c) images and/or sounds; d) distribution data; e) food webs; f) literature. This information can also be used to establish conservation policies, if we are able to answer the following questions: What species are found here? Are they threatened? What are their needs? How can impacts be minimised? How can habitats be restored? But to be able to fully implement these policies in a changing climate scenario, we must be able to answers also: Which species will be affected? How will their ranges be affected? Can they colonize more favourable regions? Will pest species benefit? In order to be able to do that we will need to have additional, and more accurate, data on Climate Change Scenarios.

It is interesting to stress that most of the major points raised in the BIOTA + 10 workshop, and raised by the Stirring Committee of the BIOTA/FAPESP Program are similar to the conclusions of the most recent (May/2009) Electronic Conference of the **European Platform for Biodiversity Research Strategy (EPBRS/http://www.epbrs.org/epbrs/event/show/21)**.

Ideally **SinBIOTA 2.0** will be developed to allow an incremental implementation of modules, importing data from the present SinBiota and following the Reference Document with flexibility to incorporate changes to better accomplish the needs established and required by BIOTA/FAPESP researchers.

3.3 - Biodiversity Inventories & DNA Barcoding

As shown in **Figure 8**, and in more detail in **Figure 12** there are at least 8 watersheds in São Paulo State – Alto Paranapanema, Medio Paranapanema, Pontal do Paranapanema, Peixe, Aguapei, Baixo Tiête, Baixo Pardo and Grande for which our present knowledge is not enough consistent to support indication of priority areas for biodiversity conservation or restoration.

Figure 12 – The 8 watersheds of the State of São Paulo where biological data available is not sufficient to allow recommendations of priority areas for biodiversity conservation and/or restoration.

Therefore, in the coming years the BIOTA/FAPESP Program must stimulate biodiversity inventories in these areas, but preference should be given to multitaxa inventories using standard quantitative sampling methods including evaluation of population size and structure, to allow better comparisons and analyses. Considering that these areas do not host strong research institutions, sampling could be done in expeditions following methods similar to those used by CI's Rapid Assessment Program/RAP (http://science.conservation.org/portal/server.pt?open=512&objID=428&mode=2&in_hi_userid=127745&cached=true) or Biodiversity Assessment and Planning/ BioRap (Faith et al, 2008).

We still do not have published check lists of the well known taxonomic groups (Angiosperms, Cryptogams and Vertebrates, just to mention the better studied), and training more taxonomists is always a rightful demand in a State with an extremely diverse biota. So inventories are still needed, but associated with traditional taxonomy we see as imperative for the BIOTA/FAPESP Program to incorporate new approaches, such as metagenomics for microorganism (Finlay, 2002) and DNA barcode sequences "a new technique that uses a short DNA sequence from a standardized and agreed-upon position in the genome as a molecular diagnostic for species-level identification, and as these barcode sequences are usually very short, they can be obtained reasonably quickly and cheaply (http://www.barcoding.si.edu/).

Although significant descriptions of Brazilian species are just about 250 years old, we already have many names for the same species, as some of them have been described more than once, species moved to new genus, were split into multiple species concepts or merged into one species concepts, as a result information related to a species may be found under many different names. Therefore, taxonomic experts are increasingly needed in research programs like the BIOTA/FAPESP, and their training must be a priority.

Within this objective the BIOTA/FAPESP Program should foster cooperation with international initiatives like GEOBON (Scholes et al 2008).

DNA Barcoding

The comparisons of DNA sequences have been fundamental for biodiversity studies and for the inference of the relationships among the different groups of organisms. Short DNA, sequences (~400-700 base-pairs, bp) of standardized molecular markers that aid species identification have been denominated DNA barcodes (Stoeckle 2003). The DNA barcoding technique generates a great amount of data in relatively short time and is an additional tool to be aggregated to the more traditional alpha taxonomy. These data, organized and available in banks, can be used for many different types of research, including biodiversity screenings, conservation and the detection of cryptic and exotic species; development of DNA probes for various applications, taxonomy and phylogenetic studies, ecophysiology, forensics, human health, agriculture etc. The main goal of the DNA barcoding system is to be an accurate, rapid, cost-effective and universally accessible DNA-based system for species identification. There are many taxonomic groups for which the identification of species is notoriously difficult due to a relatively simple morphology and anatomy; convergent morphology; phenotypic plasticity; and complex life-cycles with heteromorphic stages. This methodology also can be used even when traditional techniques cannot be applied, such as just a part of the organism available, juvenile stages, etc. Barcodes in association with other data contribute to the knowledge of phylogeny and biogeography helping to understand the mechanisms that generate the biodiversity. This system is quite recent and most studies have focused on animals using the 5?-end (~650 bp) of the mitochondrial gene coding for cytochrome c oxidase subunit I (COI; Herbert et al. 2003). However, this same region has been used with variable degrees of success in other groups of organisms (Golding et al. 2009). Even though different molecular markers may be necessary, there is no apparent limitation to the use of this technique in any taxonomic groups.

Central to the DNA barcoding enterprise is a database of previously identified reference specimens and their corresponding DNA barcode sequences. This requires taxonomists to apply their knowledge and to provide identifications of specimens that can then be barcoded (Golding et al. 2009). Barcoding databanks have to be based on a direct link between DNA sequences and taxonomic information therefore, vouchers must be deposited within collections in museums, herbaria etc. Once a database is available, the large scale identification of species becomes rapid and accurate (Savolainen et al. 2005).

Several natural history museums, herbaria and other institutions proposed an international initiative called Consortium for the Barcode of Life/CBOL (http://www.barcoding.si.edu/), launched in May 2004 and devoted to developing DNA barcoding as a global standard for the identification of biological species. The first international congress on DNA barcoding was in London in 2005 (Savolainen et al. 2005). CBOL has more than 170 member organization from more than 50 countries, including only five in Brazil (one in the State of São Paulo at UNICAMP).

Considering the high biodiversity of the State of São Paulo, the previous knowledge background including the initial 10 years of BIOTA, the presence of large museums and herbaria collections, a natural step for the program is to start a large scale DNA barcoding program. In the last decade, FAPESP has also fomented a Genome Project through the network ONSA (Oragnization for Nucleotide Sequence and Analysis; http://watson.fapesp.br/onsa/Genoma3.htm), which promoted large scale DNA sequencing of bacterial genomes and transcriptomes of various organisms, including humans and plants. Therefore, the State of São Paulo also hold many molecular biology facilities and trained researchers to carry large scale DNA sequencing.

4.3 – Marine biodiversity

Brazil has a cost of about 8,000km in length, adjacent to over 800,000 km^2 of continental shelf, spreading from 4 ^{o} N Cape Orange to 34^o S at Chui Ab´Saber, 2001. The large Brazilian coastal and continental shelf features depicts a challenging array of ecosystems which encompass a diversified assembly of environmental settings that refuges a huge marine biodiversity, nowadays also referred as “blue Amazonian”. The knowledge of this fantastic biological resource is a challenging because only a small fraction of this ecosystem is known. For this reason marine inventory has to proceed in conjunction with bioprospecting for marine natural products.

In the first phase of the BIOTA/FAPESP Program emphasis has been given to the coastal region between São Sebastião and Ubatuba, the northern coast of the State of São Paulo. Now, in this second phase we need to repeat this successful experience, focusing the central and southern coast of the State, including the large mangrove areas of the mouth of the Ribeira do Iguape River.

Another focal area of interest, not only for biodiversity inventories, but also to establish the level of depletion of fisheries and to produce environmental data to improve regional climate change models, is the oceanic region of the State of São Paulo. This is an area that will, in the near future, suffer significant impacts due to its large reserves of oil and gas.

In January 2009 the government of the State of São Paulo established three large Areas of Environmental Protection (APA Litoral Norte, APA Litoral Centro, APA Litoral Sul), each one divided in many sectors (for instance APA Litoral Norte – Sector Cunhambebe, Sector Maembipe and Sector Alcatrazes) to be able not only to protect, prohibiting for example overfishing, especially by industrial-scale operations, but also to plan human interventions in the coastal area of the State. Along the next ten years the BIOTA/FAPESP Program may produce data to improve management of these Areas of Environmental Protection.

Coastal and marine ecosystems have been heavily impacted by human activities, with degradation leading to reductions in mangroves, coral reefs and fisheries (CBD, 2006). Overfishing is an important cause of biodiversity loss associated with food production, especially in marine areas.

Some of the specific goals, reinforced during the BIOTA + 10 Workshop, are: a) to include spatial-temporal studies of mangroves, as a key ecosystem for the reproduction of economic important fishes, oysters and Crustaceae, as well as an important source of income for local population leaving from traditional low impact methods of fishing; b) determine and monitor population status of economic important fish and Crustaceae species; c) use data generated for some flag species, like marine turtles (see for instance Projeto TAMAR http://www.tamar.org.br/ingles/), to improve biodiversity conservation policies; d) identify endangered species, mapping their occurrence, status of the population and actions to reduce their extinction risk; e) identify invasive species, monitoring their occurrence, expansion rate and implement control actions; f) training of taxonomists for key taxa, by existing Graduate Programs and/or by inviting experts from abroad and establishing academic partnerships; g) stimulate bioprospection of marine organisms, as a potential source of new lead-molecules of economic interest.

The Marine Biodiversity Working Group of the BIOTA + 10 workshop also acknowledge the importance of strengthening the links and cooperation with The Ocean Biogeographic Information System/OBIS (http://www.iobis.org/) already established by the BIOTA/FAPESP Program.

But perhaps the most important issue of marine and coastal environmental are the interactions between living organisms and processes like hydrodynamics, water temperature, salinity and acidity, sedimentation and turbidity. There is an absolute vacuum of critical information, not only regarding biodiversity but also ocean interactions with atmosphere. Acidification due to increase of atmospheric CO_2 may have a great impact in all marine organism with calcium carbonate structures, like mollusks, calcareous algae and coral reefs, as been shown recently by Hall-Spencer et al (2008), but there are very few studies in Brazil (Francini Filho et al, 2008) and none southern than Espirito Santo.

The particular requirements of this kind of study may require a specific call of proposals to stimulate the establishment and consolidation of multidisciplinary and multi institutional research groups organized in five years long Thematic Projects.

Marine organisms also represents valuable sources of new biologically compounds, and over the past 50 years, approximately 20 000 natural products have been reported from marine flora and fauna. Natural products especially those from terrestrial plants and microbes, have long been a traditional source of ca. 60 % of drug derived molecule in the market. Modern pharmaceutical discovery programs owe much too natural products. Indeed, pharmacologically active compounds from the sea attracted the interest after the discovery of unusual *arabino*- and *ribo*-pentosyl nucleosides obtained from marine sponges collected in Florida, USA. The compounds eventually led to the discovery of anticancer derivatives Ara-A (vidarabine) and Ara C (cytarabine), two nucleosides in clinical uses for decades. Recently, came from the sea the most potent drug to treat chronic pain. It was approved by FDA, in 2004, as ziconotide/Prialt, and it is a natural peptide isolated from piscivorous marine snail *Conus magnus* (Molinsky et al 2008).

4.4 – Phylogeography

Although the term phylogeography was coined in 1987, this field of study has existed for much longer. Phylogeography is the study of the historical processes responsible for the contemporary geographic distributions of individuals, populations and species. It interprets the observed distribution of phenotypic and genetic differences in space in a historical framework that allows to study the processes creating this divergence. The study of phylogeography is accomplished by considering the geographic distribution of individuals in light of the patterns associated, for example, with a gene genealogy (Avise, 2000). It describes geographically structured genetic signals within and among species. The explicit focus on a species' biogeographical past sets phylogeography apart from classical population genetics and phylogenetics (Knowles & Maddison, 2002). Some past events, like population expansion, population bottlenecks, vicariance, and migration, can be inferred by the phylogeographic approach. Recently developed methodologies integrating coalescent theory or the genealogical history of alleles and distributional information can more accurately address the relative roles of these different historical forces in shaping current patterns (Cruzan & Templeton, 2000).

Phylogeography also can provide important historical perspectives on community composition. History is relevant to regional and local diversity in two ways: (1) the size and makeup of the regional species pool results from the balance of speciation and extinction; (2) at a local level community composition is influenced by the interaction between local extinction of species' populations and recolonization (Schneider et al., 1998). Phylogeography can help in the definition of relevant areas for conservation. Phylogeographic analyses have also played an important role in defining evolutionary significant units (ESUs). An ESU is a unit of conservation below the species level that is often defined on unique geographic distribution and mitochondrial genetic patterns (Moritz, 1994).

Viruses are informative to understand the dynamics of the evolutionary process due to their fast mutation rate and short generation time. Phylogeography is an important tool to understand the origins and distributions of different viral strains. A phylogeographic approach has been taken for many diseases that threaten human health, including dengue fever, rabies, influenza, and HIV (Holmes, 2004). A phylogeographic approach will likely play a key role in understanding the vectors and spread of avian influenza (HPAI H5N1), demonstrating the relevance of phylogeography to the general public.

In the previous decade of the BIOTA/FAPESP Program few efforts were directed to the phylogeographic studies. At the same time the phylogeographic methodology experienced a vertiginous improvement. Since this multidisciplinary field of science is highly relevant for a better understanding of the biota, and for its proper conservation, it is necessary to analyze different taxonomic groups under the perspective of the phylogeography.

Phylogeographic studies also bring the need for better knowledge of past biota, climate patterns and vegetation distribution. Therefore, in the next ten years paleogeographic studies will also deserve special support within the BIOTA/FAPESP Program. This decision is fully in accordance with DIVERSITAS' core project bioGENESIS, strengthening the partnership established in 2006 (http://www.diversitas-international.org/index.php?page=core_biogen_endorsedprojects)

4.5 – Invasive species & GMOs

Biological invasions are considered to be one of the most fast-moving manifestations of global change and a mounting threat to biodiversity (Sala et al. 2000).

The definition of invasive species is still arguable (Valéry et al 2008), because some definitions focus more on the process of interchange, whereas others focus more on impacts. But for the purpose of biodiversity conservation, invasive species can be defined as a non-native species to the ecosystem under consideration and whose introduction causes or is likely to alter ecosystem functioning and/or ecosystem services, bringing, directly or indirectly, environmental and/or economic harm (Mooney & Hobbs 2000). This definition includes Genetically Modified Organisms/GMOs released in nature (Scott, 2001).

Invasive species can affect indigenous biodiversity by out competing native species through preemption of space and resources, through predation, and by introducing diseases. Plants and animals are being carried around the globe intentionally or unintentionally by humans at rates that far exceed the background rates for biotic exchange, and these rates are likely to increase as globalization proceeds. Intentional cases include the introduction of new food plants, ornamentals, game animals, pets, etc. Unintentional introductions arrive in ballast water, on imported fruit and vegetables, on the shoes and clothes of travelers, in imported wooden furniture, on exported logs, and in mud on vehicle tires, to mention a few of the main avenues of introduction. Serious invaders, once established, tend to move very quickly. Because many invasive plant species are weedy in nature, invasive species can also affect agriculture, forestry, fishing and water supplies (Arroyo et al 2009).

Ecologists in general list five or six types of human related “causes” of extinction, placing habitat destruction as the greatest threat. Due to its characteristics, and the increasing speed of the process, a growing number of experts are ranking invasive species as a higher threat to biodiversity conservation than pollution and overexploitation are. The potential impact of Genetically Modified Organisms released in native ecosystem is yet to be established.

In a recent publication (Arroyo et al 2009) have shown that Latin American countries have been invaded by almost all recognized invader groups, including, plants, vertebrates, invertebrates, microorganisms and fungi. From the list of 100 of the World’s Worst Invaders, more the 50% are present in Latin America. Previous research, developed within the BIOTA/FAPESP Program, has identified that in more then 2/3 of the Cerrado remnants of the State of São Paulo African grasses are already present (Durigan et al 2004)

Nevertheless, only recently governments and environmental groups started to address this problem (Luken & Thieret 1997; Nichols et al, 1998; Parker & Reichard 1998). The growing concern and the lack of scientific information about invasive species in São Paulo State, led the State’s Secretary of Environment to establish, in May 2009, a Special Task Force to evaluate the extension of the problem, and propose actions to reduce the impact caused by these alien organisms (SMA 2009).

The contribution of the BIOTA/FAPESP Program in this area is not only developing tools to assess the impact of alien invasive species in terrestrial, fresh water and marine ecosystems, but to do this in the context of the science of Early Warning Systems. Detailed biological information on species may also help to develop modeling tools to forecast possible future threats, anticipating actions to mitigate impacts.

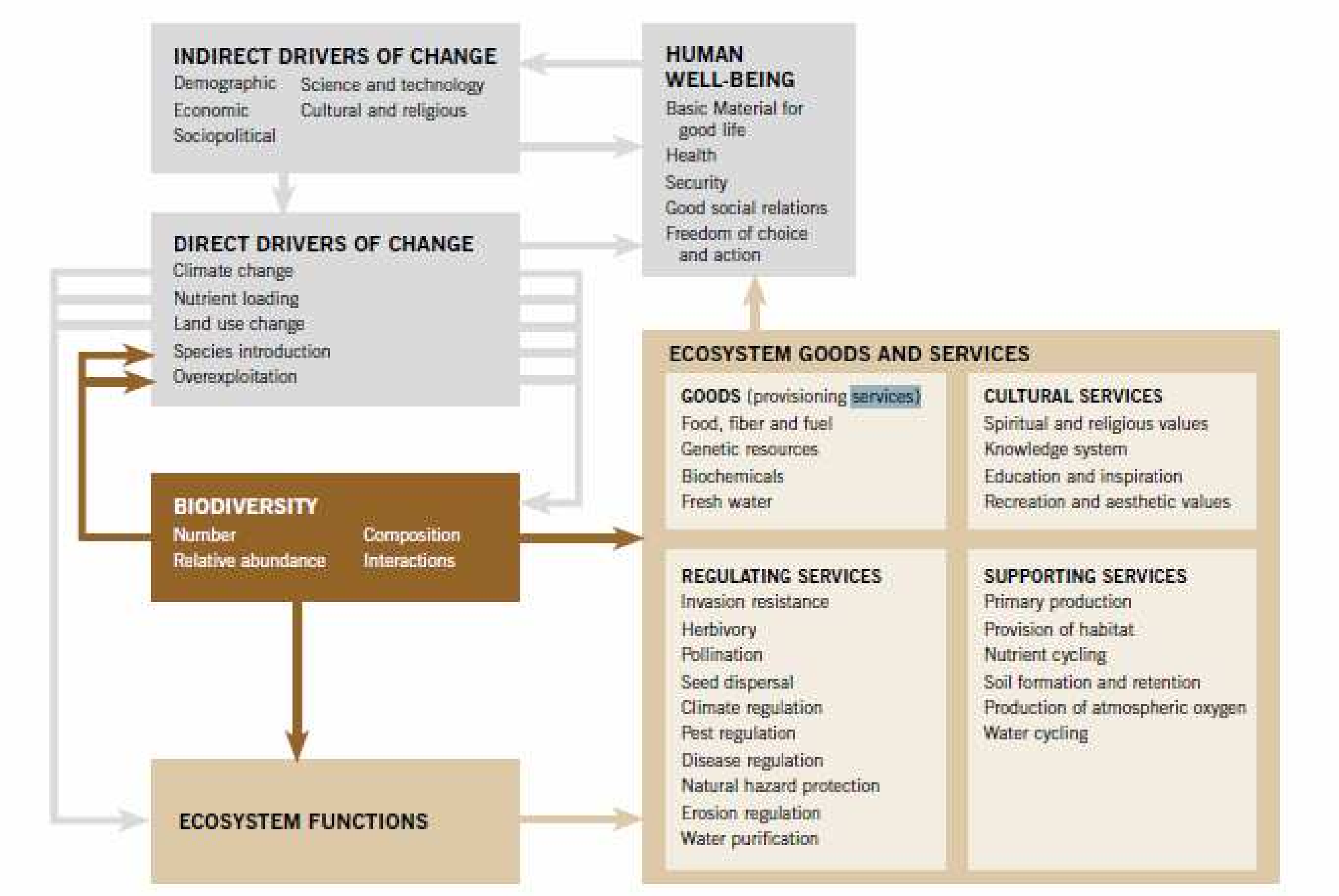
Another area of novelty that can be explored by research within the BIOTA/FAPESP Program is the synergy between invasive species and global climate change, which may have an exponential effect upon biodiversity loss.

4.6 - Landscape Ecology & Ecosystem functioning and services

As a result of the first phase of the program, it is clear that landscape ecological metrics could be useful as species diversity indicators, and thus as a valuable tool for conservation planning. The potential of this instrument should be better developed, defining which are the best metrics, for which group of species, and in which scales this procedure should be developed.

BIOTA/FAPESP Program also provide a unique opportunity to combine good land cover mapping with an extensive biodiversity database, and then to develop models of habitat use, to test the existence of structural thresholds for species occurrences, and to forecast future changes in land use on species diversity.

The services provided by healthy, biodiverse ecosystems are the foundation for human well-being (**Figure 13**). Ecosystems not only provide essential goods (like food, water, fibers, medicines) but also irreplaceable services, such as provision of fresh water; soil stability reducing superficial erosion and the siltation of rivers, reducing floods; pollination for natural and agro-ecosystems; fisheries; regulation of diseases; pest control; the ability of the atmosphere to cleanse itself of pollutants; as well as places of spiritual, religious and recreational value.



Biodiversity is affected by drivers of change and also is a factor modifying ecosystem function. It contributes directly and indirectly to the provision of ecosystem goods and services. These are divided into four main categories by the Millennium Ecosystem Assessment: goods (provisioning services) are the products obtained from ecosystems; and cultural services represent non-material benefits delivered by ecosystems. Both of these are directly related to human well-being. Regulating services are the benefits obtained from regulating ecosystem processes. Supporting services are those necessary for the production of all other ecosystem services.

Figure 13 - Biodiversity, ecosystem functioning, ecosystem services, and drivers of change. Source CBD Global Biodiversity Outlook 2 (CBD 2006)

Biodiversity loss disrupts ecosystem functions, making ecosystems more vulnerable to shocks and disturbances, less resilient, and less able to supply humans with needed services (**Figure 13**). Furthermore, the contributions of ecosystems to human societies are likely to become all the more apparent as environmental change accelerates. Biodiverse ecosystems tend to be more resilient, and can therefore better cope with an increasingly unpredictable world (CBD, 2006).

Humans have been using, transforming and impacting natural ecosystems in an increasing intensity and frequency, leading to degraded systems with low or no resilience. It is now time to stop and reverse this degradation process, and to restore those systems in order to sustain their ecosystems services and biodiversity, even in human modified landscapes. A successful restoration program will need to consider ecological processes at different levels. Particularly, human actions occur at the landscape level, in heterogeneous mosaics of human and natural land covers, and thus restoration efforts should consider the landscape heterogeneity and context. There are several synergies between Restoration Ecology and Landscape Ecology, two particularly new research fields, which should be explored in a near future. Landscape Ecology can give good insights about where, how and when restoration would be more efficient. On the other hand, restoration programs are unique opportunities to develop experimental research at the landscape level with satisfactory control and replicate design. According to Edward Wilson, "t*he next century will, I believe, be the era of restoration in ecology*".

4.7 – Applied ecology and human dimensions in biological conservation

Conservation biology has been considered as a crisis discipline (Soulé 1991) because it deals with the causes and consequences of biodiversity loss. In such context, the development both technological tools and conceptual basis are necessary to perceive, identify and solve problems. However, how and when should humans intervene in nature is rarely consensual. On the contrary, the debates about such questions often brought conflicting points of view such as naturalism vs humanism, applied vs theoretical sciences, and ecosystemic vs evolutionary ecological approach. More recently, Geography and History originated two different perspectives to understand anthropogenic changes in natural environments, respectively Landscape Ecology (Forman 1995) and Historical Ecology (Balée & Erickson 2006). As usual in science those debates are generally impregnated with ethical and esthetical values (Kuhn 1996). However, some points can come up from these conflicting points of view and effectively contribute to both technological and conceptual development of this field.

Human impacts on Earth can be compared to the great geological disasters that resulted in massive extinctions (Ehrlich & Ehrlich 1981, Soulé 1991, Wilson 1992, Meffe & Carroll 1994). However, the comprehension of this as a planetary process is also uniquely human. Such comprehension demands both applied and theoretical scientific development in order to deal with real (not imaginary) problems (Ford 2000). Intriguing evolutionary questions involve the sometimes surprising adaptive capacity of certain organisms to dwell in altered and/or changing environments (Ferrière et al. 2004) in ecosystems that apparently lost most of their structure and functionality. In such circumstance, not only space but also time (in number of generations) should be considered in order to understand the patterns of distribution and abundance of species (Simpson 1949). It is also necessary to determine in which level (from genes to the landscape, including individuals, populations, communities and ecosystems) should we intervene in nature in order to identify and solve problems of biodiversity loss (Caughley 1994).

The following directions have been established in BIOTA + 10 Workshop in June 2009 for the next 10 year of BIOTA/FAPESP Program

1) **General**:

a) Biological surveys and monitoring at population level should be stimulated in order to fulfill geographic and taxonomic gaps in our knowledge of local biodiversity as well as possible shifts in population sizes that could threat species conservation;

b) Research on the role of biodiversity in supporting ecosystem functions and services should also be stimulated;

c) Research on wildlife management should pursue the following goals:

- To increase depleted populations (i.e., management of endangered species);
- To decrease oversized populations (i.e., control);
- To promote sustainable use of economic species; and;
- To promote resilience in coupled social-ecological system in order for them to persist in face of natural or human-made disturbances;
- To improve biodiversity measurements;
- To monitor other populations in order to diagnose as early as possible population shifts that could threat species conservation (i.e., biodiversity monitoring).

2) **Conceptual basis**

Emphasis on spatial-temporal dimensions in different scales should be prioritized by the Program. This would bring two conceptual advances: the insertion of adaptive evolutionary (i.e., behavioral-ecological and/or genetic) processes related to anthropogenic pressures in ecological studies and the insertion of human historical dimensions in conservation initiatives. This would improve the dialog between biological and human sciences and also the establishment of an interdisciplinary approach in the Program.

3) Technical development

The development or improvements of the following aspects were considered priorities for the Program: sampling systematization and improvement on abundance estimation in biological surveys, valuation (economic and non-economic) of biodiversity, documentation and analysis of biodiversity resource uses and management processes, and adaptation of the existing Biota database to encompass data on human actions, resource users and other stakeholders, historical, social, political and economic context of study areas, and ethnoecological data**,**

4) Institutional articulation

Research projects congregating Graduate Programs and both governmental and non-governmental organizations that work with biological conservation should be stimulated by the Program. This would improve our capacity to generate knowledge and build new capacities within academia and other sectors to apply such knowledge within the various dimensions of biological conservation.

4.8 – Modeling & Climate Change

Modeling species geographic distributions (SDM) and ecological niche modeling (ENM) (Elith & Graham 2009) are critical problems in conservation biology. Recent developments in geographic information systems, as well as modeling tools such as Genetic Algorithm for Rule-set Prediction/GARP, Maximum Entropy/MaxEnt, Geographic Information System for Biodiversity Research/DIVA-GIS, Support Vector Machine/SVM, Ecological Niche Factor Analysis/ENFA, and novel methods that are being developed (Elith et al 2006), have yet to be better explored by the BIOTA/FAPESP Program.

Most of these tools use georeferenced points were a species has been collected, relating them either to climatic data or to a complex of abiotic information, to generate deterministic or probability maps of where a species may also occur in a given region. The rules of species present distribution generated by these models may be than projected for altered climatic scenarios of the future as well as for paleo scenarios.

4.9 – Short, medium and long term plans for the BIO*prospec*TA sub-program

Bioprospecta a subprogram at Biota-FAPESP, has been involved in searching for biologically active compounds from natural sources of São Paulo biodiversity, aiming potential candidates for drug development, which today is known as bioprospecting research - extract and sample collections, and sustainable utilization of biological resources, which goal is to apply multidisciplinary knowledge (botany, chemistry, pharmacology, toxicology, pharmaceutical and medical sciences) aiming to discover lead molecules for commercial purposes. This subprogram has only recently been started in the Biota-FAPESP program and has shown great potential in terms of academic results, which can be seen by the high quality of published papers, patents and human resources output (MSc, PhD-students and post-docs).

Since its creation, several projects that meet all international standards have been developed with very high scientific quality, and bring together a quite large number of phytochemistry scientists from different research lines. The research activities concerning the first step of this subprogram were focused mainly in preliminary screenings, revealing itself very useful in composing the first step of a bioprospecting program. However, it has not enough robustness to identify new chemical entities, due to the lack of pharmacological and toxicological projects, which would be performed in parallel with *in vitro* and *in vivo* screenings and thus, considered a weak point in the bioprospecting effort that has, as main goal, the discovery of novel biologically active products. To overcome these observations, new approaches for screening such as metabolomics, dereplication, and systems biology, **must be considered for long term drug discovery**, taking into account that the process of developing a novel product from biodiversity is funnel like, in which from many organisms, step by step, the most promising one(s) are selected. The following scientific plan should be considered to find promising lead molecules focused on natural products from our biodiversity.

a) Each step of the bioprospecting process will have to add a new value to the organisms, extracts, fractions and compounds. **Novel screenings for biologically active products must be considered at this program phase:** employing organisms, enzymes, proteins and genes as targets for novel applications. To screen the biodiversity at random or based on ethnobotanical information, small scale collection of material is necessary, bearing no impact on the ecosystems, or carrying risks of species extinction.

b) **The Bioprospecta program should make efforts to incorporate other recognized scientists of several biological fields (pharmacology, physiology, biochemistry, molecular biology, etc),** vital to investigate the mechanism of action of the most interesting substances. This is a critical point to add values to these substances, which is indispensable for future partnership with industries.

c) **Pharmacological and toxicological assays** are also fundamental adding value to standard extracts (herbal medicine) and pure compounds. Several organisms, extracts and compounds may lack interest, e.g. due to toxicity of the chemical constituents. It should be noted, however, that failure at this stage does not mean that the compound or organisms loses interest for further research. It has been shown that the development of new screens, show “old” compounds to have valuable new activities.

d) The storage of all data, as well as extracts and compounds is of great importance for future datamining. In this process there is a increasing of complexity, starting with a simple screening assay and ending with clinical trials. The datamining must be the alternative for storage important information for the program however, it is not the tool for stimulating partnership and collaborations among the groups.

e) In June 22, 2006, the federal government signed a Decree 5813/06, which approves the uses of medicinal plants and phytotherapy in the National Health System (SUS). There are 71 plant species selected for chemical and pharmacological studies aiming to produce high quality phytomedicines, and the research on medicinal plants should be one goal of the Bioprospecta for the next phase.

f) The collaboration with companies for projects in advanced phases must be stimulated, and this subprogram may be an alternative for partnerships with cosmetic, pharmaceutical and other industrial sectors, interested in bio-products.

   The São Paulo's extensive biodiversity, is a source to find novel products, or concepts, that can translate into novel sustainable exploitation through commercial activities, and thus carrying benefits to the State.

g) Academic workshops on the last advances on natural products chemistry, pharmacology, toxicology, molecular biology, metabolomics, and systems biology is essential to induce close collaborations among the participants of the subprogram.

h) Intense discussions with national and multinational companies. A mechanism to explore commercialization of the patents generated in the sub program is not yet defined. A business development agency or unit with experience on the global market would be useful in this context. In the commercialization of promising products, patents may eventually generate funds for the project, as well as funds for the State.

4.10 – Education & Public Outreach

For the survival and increment of the Biota Program is crucial to keep the flow of information open to the general society, through subsidizing education on all levels and responding to the society needs for biodiversity related issues (recovering of degraded areas, data for the support of legislation, personnel training etc).

Among the different suggestions discussed in the Workshop BIOTA + 10 was the development of a virtual museum that could serve both the academy and the society, including high quality images of types, taxonomical information, etc. This initiative would also be important to raise the visibility of Biota Program both in Brazil and in the rest of the world. Another issue was the production of an environmental atlas.

One of the main products of the Biota Program in the past 10 years is the biological collections generated or largely incremented, including zoological and botanical specimens among others. These collections are used as reference and are fundamental for any biodiversity program. Part of the collections are housed in museums and can be available to the general public also in a virtual museum or as temporary exhibitions.

In the previous 10 years the program BIOTA/FAPESP has mostly worked on the disclosure of the importance of the biodiversity studies and conservation for the State of São Paulo. For that divulgation material such as posters, field guides, videos, books and exhibitions were produced. For the next ten years the program must attract more effectively researchers from the Education field to generate research data for that can be the basis for improving and subsidize the basic education (Ensino Fundamental e Médio).

Considering the strong problems of public schools in Brazil, the program should focus on how to make available the knowledge generated in the different research projects of BIOTA/FAPESP to school communities, trying to solve the following questions: (1) How to improve the awareness of academic researchers about the basic educational needs? (2) How to promote educational research in the BIOTA Program? (3) How to transfer the generated knowledge to the school community in a way that it has a significant impact, improving the general level of student formation (including biodiversity awareness and general science education).

Plural approaches are needed to manage complex questions like the above. This diversity of approaches should be expressed in many dimensions: (1) actuation on formal and informal education; (2) development of programs focused on initial and continuing formation of teachers; (3) divulgation of Biota research projects in different communication media: scientific journals (including Biota Neotropica), games, didactic manuals, sites, blogs, science fairs, expositions; (4) participation on research projects of professionals from a variety of areas, mainly Biology, Education and Communication, aiming to produce the dialog necessary to construct solid collaborations with the basic education.

The main suggestions of concrete actions for developing good quality of educational research and make those available to society during the next ten years of BIOTA/FAPESP are:

a) Incentive researchers to include some kind of educational proposal in their projects and to take responsibility in finding partners to help in the implementation of this proposal;

b) Include activities with teachers and students of basic education as partners;

c) Orient referees to the peculiarities of education research;

d) Improve de educational part of the BIOTA site;

e) Organize meetings with researchers interested in education, aiming a better integration among them.

f) Organize events to the public, as expositions, science fairs, special activities at schools, etc.

Furthermore the Program should launch a new electronic peer reviewed journal **BIODIVERSIDADE NA ESCOLA** (Biodiversity in School) dedicate to publish data and information on biodiversity characterization, conservation, restoration and sustainable use in formats and language that can be used by Primary and High School teachers, as well as the general public.

WORKSHOP BIOTA + 10: establishing goals and priorities to 2020

3 & 4 of June 2009

Some general points of discussion were raised in different working groups and are listed below:

Databank: The databank was a main concern of the scientific community. One of the aspects raised was the possibility to expand the database to include also data collected in other states of Brazil. One concern was the idea that the BIOTA/FAPESP Program was limited only to collection of data and biological material in the state of São Paulo. This limitation occurs in the databank, but research projects can be broader and include data and collections in other places outside the state. This is particularly important in phylogeographic studies. The update and modernization of the databank is a crucial issue for the Biota BIOTA/FAPESP Program, including “data-cleaning” tools, standardization of taxonomical information and interoperability with other databank already available;

Collections: One of the main products of the BIOTA/FAPESP Program in the past 10 years is the biological collections generated or largely incremented, including zoological and botanical specimens, germoplasm banks, culture collections of microorganism etc. These collections are used as reference and are fundamental for any biodiversity program. Many of these collections are in a poor state and its specimens are stored or kept inadequately due to lack of space, appropriate storage and/or personnel. Therefore, one of the priorities of the Program is to seek possible sources of support to improve storage capability as well as the quality and availability of curators.

Habitats are disappearing very quickly, therefore, some biological samples are precious material and it is urgent that they are collected and stored in a way that they can serve for different needs, including molecular biology analyses. The collection efforts should be optimized and that can be achieved through collaboration between different projects and specialists.

All participants of the Workshop strongly recommended the inclusion of institutional Biological Collections (those with a designated curator and, ideally, registered in CGEN/MMA), such as Herbarium (including plant, algae, fungi, lichen, bryophyte, pteridophyte, as well as Pollen and Wood Collections), Zoological Collections and Culture Collections of microrganisms, algae or fungi, in any future call for proposals within the Infrastructure Program of FAPESP.

Molecular tools: The request for the use of molecular tools to aid the biodiversity studies is urgent on different levels such as populations, species, phylogeography etc. Therefore, sampling in inventories and taxonomical studies should have a standard methodology to preserve and allow DNA extraction

based other types of data should be maintained within the program.

Main themes for an interdisciplinary approach: One way of measuring the importance of the BIOTA/FAPESP Program is its capacity to answer major questions in biodiversity raised in the academy or as request of the society. During the discussions, main themes for an interdisciplinary approach were identified and past or ongoing research projects on these themes were mentioned indicating that there is both interest and previous work that could facilitate the implementation of such initiatives. Among the mechanisms to stimulate an integrated approach it has been strongly recommended to use call for proposals with specific targets and objectives; to promote workshops and/or symposia bringing the best specialists from Brazil and from abroad to discuss topics of common interest.

The Biota Program should find ways to attract and integrate researchers working on different approaches to study the biodiversity. This could be achieved through several mechanisms, such as: i. providing an excellent databank including different tools for the study of biodiversity; ii. providing the means for collaboration among different research groups, for example facilitating the access to information through excellent web page on the past and ongoing projects in the program; iii. organizing courses, workshops and symposia; iv. supporting personnel training and maintenance in a more continued way; v. giving support for licenses and publication.

Public outreach: For the survival and increment of the Biota Program is crucial to keep the flow of information open to the general society, through subsidizing education on all levels and responding to the society needs for biodiversity related issues (recovering of degraded areas, data for the support of legislation, personnel training etc).

Virtual Museum: Among the different suggestions discussed in the group were the virtual museum that could serve both the academy and the society, including high quality images of types, taxonomical information, etc. This initiative would also be important to raise the visibility of Biota Program both in Brazil and in the rest of the world. Another issue was to incorporate paleoecological information to the Program and the production of an environmental atlas.

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