"**Comprehensive Protected Areas System Composition and Monitoring**" has been prepared as a contribution to the Vth World Parks Congress in Durban, South Africa, September 8-17, 2003. Most countries of the world have at least a collection of protected areas, and have signed the Convention on Biological Diversity, while considerable international funding has been established to help developing countries finance their conservation commitment. Yet only few countries have systematically selected biodiversity to their protected areas. The methods and tools of this book are based on solid scientific principles as well field experiences of more than a decade of experimenting in a variety of countries. Important conservation issues include:

- **identification of ecosystems and species assemblages** through surrogate methods
- **the minimum sizes of protected areas** for ecologically durable conservation
- **costs of selected protected area systems**
- affordable monitoring practices with a **stand-alone monitoring database**.

The efficient composition of protected areas systems based on solid biological criteria has become one of the most urgent issues in biodiversity conservation, as, (1) the last remaining wild areas with still unprotected species are likely to disappear over the next decade or two, (2) climate change will wipe out countless species, even in protected areas and (3) the required funding to set up and maintain the world's protected areas is structurally inadequate.

A diversity of scientific backgrounds and management skills and different regions of operation of the members of the **ecological task force** facilitated the development of methods and tools for world-wide applicability. Their joint experience unites **tropical, boreal, polar, terrestrial, aquatic, zoological botanical, technical and financial management expertise**.

**Dr. Ir. Daan Vreugdenhil**, director of the World Institute of Conservation & Environment, has worked for 30 years in planning and management of natural resources of temperate and tropical terrestrial and aquatic environments. His career took him across 5 continents, while dealing with dry and humid tropical as well as temperate ecosystems. His background includes vegetation and animal ecology as well as natural resources and national parks management.

**Prof. Dr. John Terborgh** is Professor of Environmental Science and Botany and co-director of the Center for Tropical Conservation at Duke University, in Durban, North Carolina. He is one of the driving forces behind the Wildlands Project, a far-reaching effort by scientists and activists to develop better ways of protecting nature, wilderness and biodiversity. He has carried out research in both tropical and temperate climate conditions in the Americas.

**Prof.Dr. A.M. Cleef**, teaches Actuo-ecologie at Amsterdam University and Tropical Vegetation Ecology and mapping at Wageningen University. For almost four decades, he has conducted vegetation -ecological research in the Andes and the mountain ranges of Central America.

**Dr. Maxim Sinitsyn** , Managing Director of the International Forest Institute in Moscow, is ad Zoo-geographer/ecologist with vast research and conservation management experience in the boreal and tropical regions of Russia.

**Dr. Gerard C. Boere** is a zoo-geographer/ornithologist with a worldwide reputation in international conservation. His professional realm spans the pathways and wetlands of migratory birds from the high Siberian arctic to Southern Africa.

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Comprehensive Protected Areas System Composition and Monitoring

# COMPREHENSIVE PROTECTED AREAS SYSTEM COMPOSITION AND MONITORING

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**Gerard C. Boere**
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WORLD PARKS CONGRESS 2003 DURBAN BENEFITS BEYOND BOUNDARIES

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## ABOUT THE TASK FORCE

**Dr. Ir. Daan Vreugdenhil**, director of Conservation & Environment, has worked for 30 years in planning and management of natural resources of temperate and tropical terrestrial and aquatic environments. He graduated (cum laude) from Wageningen University in both vegetation and animal ecology and natural resources management. He started his career as project officer of the IYF, preparing the youth contribution to the **European Conservation Year 1970**. His tropical career started with a position as a resources management officer with FAO, with projects in Africa and South America. After return to the Netherlands, he became senior administrator with the Netherlands' Ministry of Works and Water, **Rijkswaterstaat**, where he was responsible for three different integrated programmes involving budgetary management of Euro 300,000,000 per year. In 1990 he returned to the international sphere as Chief of the Natural Resources Management Unit at **DHV-Consultants**, for which he developed and lead projects in Eastern Europe, Asia and Costa Rica. In 1992 he joined the **Inter American Development Bank** as an environmental specialist. In 1995 he became director of the **World Institute for Conservation and Environment**, **WICE** an independent thinktank and advisory institute. His work and travels have taken him to more than 70 countries of the world, in many of which he has been involved in some kind of advisory task. His life-time passion for national parks conservation culminated in coordinating this **task force of independent conservationist/scientists** whose joint life-time experience and expertise is reflected in the current document.

**Prof. Dr. John Terborgh** is Professor of Environmental Science and Botany and co-director of the Center for Tropical Conservation at Duke University, in Durban, North Carolina. He is one of the driving forces of the Wildlands Project, a far-reaching effort by scientists and activists to develop better ways of protecting nature, wilderness and biodiversity with the ultimate goal to establish an effective network of nature reserves through North America. He has carried out research in both tropical and temperate climate conditions, particularly in Manu National Park in Peru.

**Prof. Dr. A.M. Cleef**, teaches Actuo-ecologie at Amsterdam University and Tropical Vegetation Ecology and mapping at Wageningen University. For almost four decades, he has conducted vegetation and paleo-ecological research in the Andes and the mountain ranges of Central America and the reputation of his life-time involvement in the ECOANDES research project has made him an international recognised authority in tropical vegetation ecology.

**Dr. Maxim Sinitsyn** graduated from the Moscow State University as a Geographer (Zoo-geography and -ecology, Biogeography) and later received his Ph.D. at the Institute of Ecology and Evolution of the Russian Academy of Sciences, where he has been working as a staff scientist. Last year he became the Managing Director of the International Forest Institute, in Moscow. His specific area of research is the design of protected nature areas, wildlife and forest ecosystems sustainable management and mammal ecology. Over the past decade, he managed several international projects in different eco-regions including arctic territories, boreal forests and wetlands.

**Dr. Gerard C. Boere** graduated (cum laude) in 1971, at the Free University in Amsterdam in zoo-geography, bird migration and palaeontology. His PhD (1977) was on the international importance of the Dutch Wadden Sea for migratory Arctic breeding waders. As Head Flora and Fauna Conservation of the National Forest Service from 1977-1987 he was involved in almost every conservation issue in the Netherlands; in this function he e.g. prepared the reintroduction of the Beaver into the Netherlands. Since 1987 he works for the International Biodiversity Conservation Division of the Dutch Ministry of Agriculture, Nature and Food Quality in which capacity he was Head of the Dutch delegation to the Ramsar and Bonn Conventions. He developed e.g. the African Eurasian Migratory Waterbird Agreement and co-ordinated for 10 years the bilateral co-operation with the Russian federation e.g. on Arctic conservation and was and is active in many important international positions. He is presently seconded by the Dutch Government to Wetlands International. Throughout he has extensively dealt with the problems of the establishment and management of protected areas and protected area networks. In 2000 he was Knighted by Queen Beatrix and become an Officer in the Order of Orange Nassau; he also received the WWF International Award for Conservation Merit and the Golden Medal (as the first foreigner ever) from the Russian Conservation community".

**Ingeniero Victor Leonel Archaga** has a degree in tropical forestry and has served twice as director of the Protected Areas department of the Honduran Forest Service during which periods he was intensively involved in the conceptualisation and excecution of protected areas system analysis and monitoring programme development. He is currently director of the World Bank/UNDP Honduras protected areas project PPROBAP and is one of the most renowned conservationists in Central America.

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# COMPREHENSIVE PROTECTED AREAS SYSTEM COMPOSITION AND MONITORING

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**ABSTRACT**

*The World Parks Congress in Bali in 1982 had set a target to set aside 10 percent of the world's terrestrial landmass as protected areas, but it did not indicate which lands. For the majority of the more than 175 countries that have ratified the Convention on Biodiversity it is unknown what their ecosystems and species are and where they occur. Only through extremely efficient selection of spaces to systems of truly protected areas can a significant proportion of the species of the earth be given a chance to survive. Efficiency of selection becomes even more important, when we realise that many species in protected areas will still perish as a result of* ***natural*** *ecological processes taking place in protected areas that will/have become islands of nature in a human-dominated world. In addition to such processes, some anthropogenic influences cannot be stopped at the boundaries of protected areas. Most and for all, climatic change will take a heavy toll, even in the best-managed protected areas. The more species we can select to protected areas systems, the more species will have a chance to weather out the storm of ecological destruction that is currently devastating this planet's biodiversity. The conservation of the world's biological heritage in a human-dominated world is a scientific challenge on a par with cracking the genetic code or sending humans to the moon. It requires the collaboration of all sectors of society and a great variety of disciplines, but most and for all, ecological science. If the ecological foundations of conservation are ignored, then all other efforts are likely to fail.*

*Based on concept development and experimentation since 1992, "Comprehensive Protected Areas System Synthesis and Monitoring" has been developed by a task force of renowned experts in all the primary fields required to bring together both the theoretical background and the institutional experience for such ambitious goal. It provides a holistic method and a toolbox for the rational design of protected areas systems that maximise species conservation through targeted selection, based on broadly accepted ecological principles. The identification is based on appropriate technology computer programmes and techniques that allow the user to identify and map biodiversity using ecological surrogates to spatially distinguish species assemblages. A monitoring programme with additional tools and manuals, builds on the initial selection as a baseline, while it gradually furthers the biological knowledge of protected areas on the basis of relevant field observations. A protected areas costing module, can help policy makers, planners and managers with the complex process of raising and distributing the finances needed to operate the protected areas systems.*

*For a long time, ecosystem mapping has been possible from aerial photographs, and this was applied in some parts of Africa, in Belize and in Western Europe on a moderate scale. Interpretation was slow and the photographs were expensive and national sets were often incomplete. As a result, the maps of natural vegetation covered only few parts of the world. It was not until the 1990s that satellite images had become effectively available to a broader gremium of scientists and biologists. Some of the first detailed mapping applications with remotely sensed imagery for the tropics was the pioneering work by Iremonger in 1993, 1994 and 1997. These were important advances as they facilitated much faster and more cost-effective mapping, particularly after the LANDSAT 7 imagery became available for less than US $500 per image in the year 2000. GIS software had also become more broadly available which can now be operated from regular desktop computers.*

*The World Bank/Netherlands Government/CCAD financed the production of an ecosystem-mapping, spanning more than 1500 km from Belize to Panama: the "Map of the Ecosystems of Central America". Ecosystems were mapped by more than 20 scientists using the "Tentative Physiognomic-Ecological Classification of Plant Formations of the Earth", developed under the auspices of the UNESCO, complemented with additional aquatic ecosystems and some floristic modifiers. The term ecosystem was used, because it was argued that areas with distinct physiognomic and ecological characteristics would not only have partially distinct sets of floristic elements, but also partially distinct sets of fauna and fungi elements. It was demonstrated that ecosystems derived from*

*such criteria could be identified in considerable detail and a short period, using satellite images and teams of experienced national biologists. This opened the way to worldwide detailed identification and localisation of ecosystems and related species assemblages. Never before was it possible to generate geographically unbiased data, as all existing databases – even in developed countries - are heavily biased by road-access, research facilities and site-choice by researchers. It now has become possible to distinguish and map partially distinct assemblages of species rapidly in considerable detail from recent datasets reflecting current situations and without aforementioned factors of bias. These ecosystem maps finally make it possible to carry out unbiased gap/presence analysis.*

*The Honduran part of that map was used to evaluate the presence and gaps of ecosystem representation in the protected areas system, SINAPH, of Honduras. An MS-Excel based spreadsheet evaluation programme called "**MICOSYS"** was used to compare the relative importance of each area and to design alternative models for protected areas system for different scenarios of conservation security and socio-economic benefits. To achieve this, very specific criteria are needed that allow differentiation of size requirements for protected areas depending on a variety of factors such as Minimum Viable Population (MVPs) and Minimum Area requirements (MARs), functionality for both terrestrial and aquatic species of animals, plants and fungi, as well as ecosystem characteristics. Solid ecological principles, enriched with some new considerations on species survival have been integrated into a holistic approach that allows the synthesis of comprehensive rational protected areas systems. New concepts are presented on the minimum required sizes of protected areas, in which not merely top predators were considered as limiting factors, but ecosystems. As far as the SLOSS (Single Large Or Several Small reserves) debate is concerned, it is clear that we will need SLASS: Some Large And Several Small reserves, the latter complementing ecosystems absent in the large areas protected areas. The method not only generates differentiation in importance of the protected areas on the basis of socio-economic and ecological factors, but it also calculates estimates of investment needs and recurrent costs. It was originally developed in 1992 for Costa Rica, but it is country-size independent and may be applied anywhere in the world. It is very flexible and may be complemented with other methods, particularly the Important Bird Areas of Birdlife International and the Rapid Assessment and Prioritisation of Protected Area Management (RAPPAM) Methodology of the WWF. The cost calculations in MICOSYS are of strategic importance. Governments all over the world have made great progress in institutionalising protected areas. But it was only a first necessary step. Adequate funding has not yet come along to meet the requirements. A realistic idea about costs is necessary to work toward finding solutions to the financing problem.*

*One of the by-products of the Map of the Ecosystems of Central America is an MS-Access-based database called **Ecosystems Monitoring Database**, for the storage of ecological field information, consisting of tracking information to support physical physiognomic and floristic information. The database has been expanded to also store information on fauna as well as essential information on the use of natural resources and visitation within an area, thus creating a tool for protected area or ecosystem monitoring. In Honduras, a monitoring approach was developed and the database had become fully integrated and made user-friendlier, so that it could also be used by park rangers.*

*The techniques used in the methodology are all known methods based on commonly accepted ecological principles The methodology has been developed, evaluated and tested for more than a decade and consists of an "appropriate technology" approach. User-friendly applications were designed in familiar programmes to be accessible to national scientists and rangers anywhere in the world. Each application may be used independently and may be customised to suit national needs. It has not been designed to replace existing monitoring systems, but to be available for countries where a database is not yet available or for individual users and or protected areas.*

**ACKNOWLEDGMENTS**

The first version of MICOSYS was developed under the guidance of Luis Constantino of the World Bank, during an assignment for Costa Rica and made many contributions to its functionality. Since then, Luis and his colleague Augusta Molnar have facilitated numerous other assignments, which allowed further development and testing of ideas. Applications of MICOSYS have been done among others with Alvaro Ugalde and Alonso Matamoros in Costa Rica, Niek Bech and Roger Wilson in Belize, Victor Archaga, Paul House and Carlos Cerrato in Honduras, Marisol Dimal in Panamá and Victor and Jacinto Cedeño in Nicaragua, each of whom were essential in providing essential local knowledge and feedback, without which the programme cannot work.

The development of the "Map of the Ecosystems of Central America", was essential in the conceptualisation of the current document. Douglas Graham, task manager of the World Bank, had become much more than a coordinating taskmanager: his background as a biologist and his clear analytical mind was indispensable for the production of the map and its finalisation; for the final report he became one of the co-authors. Obviously, this map is the work of 7 national teams and at least the names of the following participating lead-scientists must also be mentioned in gratitude: Suzan Iremonger, Jan Meerman, Wilber Sabido, Luis Diego Gómez, Wilberth Herrera, Nohemy Ventura, Raul F. Villacorta, Cesar Castañeda, Juan José Castillo Montt, Maurice Carignan, Thelma M. Mejía, Cristobal Vasquez, Paul House, Carlos Cerrato, Alain Meyrat, Alfredo Grijalva, Rob Beck, Mireya D. Correa, Luis Carrasquillo, Martín Mitre, María Stapf, Valerie Kapos, Abdiel J. Adames.

The down-to-earth thinking on protected areas monitoring were developed by Adrian Forsyth developed in the context of a GEF project preparation for Honduras. His ideas were logical and applicable and could be united with Rick Smith's practical experience and ideas on the importance of rangers into an enhanced permanent-staff-based, low-cost monitoring concept. The concepts were there, but still needed technical elaboration. The System for terrestrial ecosystem parameterization (STEP) method, (Muchoney. et al. 1998) had served as the point of departure for field analysis and the database for the map project. Many discussions with Douglas Muchoney and aforementioned scientists have lead to the development of a more ecology-oriented database for the map. This database could then be adapted for protected areas monitoring, among other things, by adding zoological concepts – with important suggestions from Jan Meerman - and information on area visitation and other use. Important feedback came from Prof. Dr. Ir. Roelof A.A. Oldeman.

Dr. Maarten Kappelle of the IUCN in Central America, Dr. Henk van der Werff of the Missouri Botanical Garden, Dr. James Luteyn, Dr. Scott Mori and Dr. Doug Daly of the New York Botanical Garden, Dr. Joost Duivenvoorden of the Amsterdam University each have provided invaluable advise concerning lowest species densities. Prof. Dr. Henry Hooghiemstra, Amsterdam University and Prof. Dr. Goetz Schuerholz, University of Victoria provided detailed peer reviews. Henk Hartogh and Willem Ferwerda of the Netherlands IUCN Committee have given great support, both technical and financial. Lesley K. Burk thoroughly proofread and edited the document, in an effort to weed out the countless sins against the English language. We like to specially mention the thorough review by Güven Eken of Birdlife International. Many factual suggestions he made could be incorporated in the document.

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# 1. INTRODUCTION

## 1.1. THE CONVENTION ON BIOLOGICAL DIVERSITY (CBD)

The year 1992 was a historical moment in the struggle for conserving the world's natural heritage, 120 years after the creation of the Yellowstone National Park in the USA had set off the creation of many large protected areas in North America. That year, in February, the IV$^{th}$ World Parks Congress was held in Caracas, Venezuela; in May, in Nairobi, the nations of the World adopted a global Convention on Biological Diversity (CBD); and in June, the United Nations held its Conference on Environment and Development in Rio de Janeiro, Brasil.

The World Parks Congresses are organised by the World Conservation Union, (IUCN), the global alliance for conservation and wise use of natural resources, that unites more than 980 member organisations from more than 140 countries (http://iucn.org). The IV$^{th}$ World Parks Congress adopted the "Caracas Action Plan" with recommendations for strategic actions for protected areas creation and management over the decade from 1992 to 2002, calling for special attention to enhancing the capacity to manage marine protected areas and to include them as major components of national system plans. The Caracas Congress devoted much of its attention to the need to build constituencies, involve major interest groups in planning and management, enhance revenue generation and financing, and assess and quantify the benefits protected areas provide.

The United Nations Conference on Environment and Development or "Earth Summit" in Rio de Janeiro was the largest-ever meeting of world leaders and a historic set of agreements was signed, including the aforementioned CBD, which was the first global agreement on the integral conservation and sustainable use of biological diversity. The CBD was signed at the Earth Summit by over 150 governments, and since then, more than 175 countries have ratified the agreement (http://www.biodiv.org/ 2002). The significance of the CBD was not only the commitment of almost all the countries of the world to promote biodiversity conservation, but for the first time in history, a funding mechanism was established that could at least launch a serious initiative for establishing biodiversity conservation programmes in countries that for compliance, would have to rely heavily on external financing and technical assistance. Launched in 1991 (http://www.gefweb.org/ 2002) as an experimental financing facility, the Global Environment Facility (GEF) was restructured after the Earth Summit for the financing of a number of environmental issues, among which biodiversity conservation. In 1994, 34 nations pledged US $2 billion in support of GEF's mission; in 1998, 36 nations pledged another US $2 billion. In many cases, national governments were willing to complement GEF financing with national funding obtained through World Bank IBRD lending (World Bank 2002). Given the support of almost all the nations of the world to the terms of the CBD and its associated financing mechanism, the CBD is the legally binding framework for biodiversity conservation efforts worldwide and for the largest source of financing targeting biodiversity conservation.

The events in 1992 had not come overnight; on the contrary, they were the culmination of many decades of dedicated and cooperative efforts of nations, international and non-government organisations (NGOs) to jointly preserve a representation of the world's natural heritage.

One of the first major international feats for the conservation movement was the African Convention on the Conservation of Nature and Natural Resources (http://www.unep.org/aeo/013.htm) in Algiers in September 1968, which set off conservation initiatives in many of the young nations in Africa. In those days, conservation had not yet become an issue of weight for development organisations, and the movement was still very much NGO-driven, lacking the financial and political backup by better-funded development institutions.

Shortly afterwards, the more specialised, but worldwide "Convention on Wetlands of International Importance especially as Waterfowl Habitat" (usually referred to as the Ramsar or Wetlands Convention, http://www.ramsar.org/) held in Iran in 1971 targeted the systematic establishment of protected areas based on specific criteria. Originally, it used birds as the main criterion for site designation, but later a policy was adopted that "Wetlands should be selected for its "List" of registered "Wetlands" on account of their international significance in terms of ecology, botany, zoology, limnology or hydrology (Ramsar Convention Bureau 1997). The First United Nations Conference on Human Health and Environment in Stockholm, Sweden in 1972, strongly stimulated the development of a number of further international agreements and conservation policies of both international organisations and individual nations. Slowly, conservation was moving onto the agenda of development cooperation institutions, most notably the FAO. In the same year, the 2$^{nd}$ World Parks Congress celebrated the centennial of the creation of the first national park, Yellowstone NP, and it launched many new ideas on how to deal with national parks and protected areas.

During the 1970s, the FAO – with strong technical support of the IUCN and WWF – spearheaded a worldwide effort to establish national parks systems in a systematic fashion. Under the leadership of Dr. Kenton R. Miller, the FAO regional office for Latin America in Santiago, Chile, developed and promoted a methodological approach for protected areas system composition, that was applied in many countries in South America, among which Chile (Miller and Thelen 1974), and Ecuador (Putney and DPNVS 1976). Numerous other countries in Latin America had FAO projects to set up a national parks system following the FAO method, but it is very difficult to get a hold of

those historical documents. If still existing, they are often deeply buried in the FAO archives and/or those of the national forestry departments or equivalents of the countries in question.

Within the context of this study, it is relevant to mention the protected areas system development in Ecuador, which resulted in the FAO project document "Estrategia Preliminar para la Conservación de Areas Protegidas del Ecuador" (Putney and DPNVS 1976). Not only was his proposal for a systematically composed protected areas system executed in full by the Government of Ecuador, but his ideas formed the point of departure for basic concepts furthered in this document.

In 1981, the IUCN, WWF and UNEP jointly launched the World Conservation Strategy, developed under the coordination and editing of Dr. Kenton R. Miller. Through that strategy, many concepts developed from the FAO regional office in Santiago found their way to many parts of the world. The strategy advocated conservation of living resources as essential for sustaining development by:

- maintaining the essential ecological processes and life-support systems on which human survival and development depend;
- preserving genetic diversity on which depend the breeding programmes necessary for the protection and improvement of cultivated plants and domesticated animals, as well as much scientific advancement, technical innovation, and the security of the many industries that use living resources; and
- ensuring the sustainable use of species and ecosystems which support millions of human communities as well as major industries. An essential element in any programme attempting to achieve these objectives is **the establishment of networks of protected areas for *in situ* conservation of species and ecosystems**.

That document was later followed by another strategic document: "Conserving the World's Biological Diversity" (McNeely et al. 1990).

In 1982, the third component of the World Conservation Strategy was intensively dealt with during the III$^{rd}$ World Parks Congress held in Bali, Indonesia. The Congress adopted what is referred to as the "Bali Declaration", which called for *'the establishment, by 1993, of a worldwide network* of *national parks and protected areas, exemplifying all terrestrial ecological regions"*. It was also agreed at the Congress that *a biogeographical approach should be used in selecting additional protected areas*. In the underlying Bali Action Plan, the objective was set to expand the worldwide network of protected areas to 10% of all terrestrial ecological regions. An important question is "if that target can meet the expectations of society and durably conserve a significant representation of the variety of life on earth"?

## 1.2. BIODIVERSITY CONSERVATION OPTIONS

### 1.2.1. *In-situ* conservation: protected areas systems

While recommendations of the World Parks Congresses are important guidelines, the CBD provides a binding agreement. For execution of the Bali Declaration, the following article in the CBD is most important:

Article 8. In-situ Conservation

**"**Each Contracting Party shall, as far as possible and as appropriate:

- Establish a system of protected areas or areas where special measures need to be taken to conserve biological diversity;
- Develop, where necessary, guidelines for the selection, establishment and management of protected areas or areas where special measures need to be taken to conserve biological diversity;
- Regulate or manage biological resources important for the conservation of biological diversity whether within or outside protected areas, with a view to ensuring their conservation and sustainable use;
- Promote the protection of ecosystems, natural habitats and the maintenance of viable populations of species in natural surroundings;
- Promote environmentally sound and sustainable development in areas adjacent to protected areas with a view to furthering protection of these areas;
- Rehabilitate and restore degraded ecosystems and promote the recovery of threatened species, inter alia, through the development and implementation of plans or other management strategies."

Two years after the Earth Summit, the IUCN published a "*Guide to the Convention on Biological Diversity"* (Glowka et al. 1994); this guide provides a solid basis on how to work with the CBD. The document stated that it considers protected areas to form the principal element of any national strategy to conserve biodiversity. A good network of protected areas forms perhaps the pinnacle of a nation's effort to protect biodiversity, ensuring that the most valuable sites and representative populations of important species are conserved in a variety of ways.

### 1.2.2. Haphazard selection and continuous pressure to expand

The word "system" in paragraph (a) implies that the protected areas of a signatory or region should be chosen in an organised and logical fashion, and together, they should form a network, in which the various components conserve different portions of biological diversity. In many countries, that is not how protected areas systems have come about. Often, protected areas systems are the result of haphazard selection. In some countries, the first – and often the largest – protected areas were chosen to protect areas of outstanding scenery or to conserve large animals, rather than for their

contribution to biodiversity conservation (Glowka 1994).

In the USA, the original selection during the first half-century since the creation of Yellowstone National Park was inspired by scenic beauty (geysers, waterfalls, canyons, etc.) as well as corporate interests, particularly of the railroad company, Northern Pacific, that had promoted the creation of Yellowstone NP from the beginning to promote tourism interests (Sellars 1997, http://www.cr.nps.gov/history/online_books/sellars/index.htm) and by going as far as keeping settlers out in anticipation of its creation. The company also played an important role in the creation of other early national parks though criteria for parks selection based on biodiversity information during the early years of the US National Parks Service were not apparent (Sellars 1997).

In Europe, many protected areas originally were hunting and forestry domains of the nobility and extremely poor and often inaccessible communal lands, although some "parks" were created for the enjoyment of flowers and birds as early as the Renaissance. It is very unlikely that the selection of protected areas was approached in a systematic and species-oriented methodological way in most countries of the world before the end of the 1960s. In fact, the European Conservation Year 1970 in Strasbourg, organised by the Council of Europe, was probably one of the first major international initiatives to promote a methodological approach. The event, however, focussed on a combination of generic planning mechanisms and the integration of nature and environment into the socio-economic planning mechanisms of the member states of the Council and biological criteria were not yet strongly developed. Through this initiative, many integrated conservation areas in Europe were created or expanded from smaller existing nature reserves such as the Lünenburger Heide in Germany and the Parcs Régionaux in France. If biological criteria were still very much nascent in most of Europe in 1970, one may suspect, that the main colonial nations of the 1950s, Great Britain, France, the Netherlands, Belgium, and Portugal, had not systematically applied such criteria for selecting protected areas during their colonial days, and that since independence, many former colonies had not yet had much opportunity to initiate systematic selection before the early 1970s.

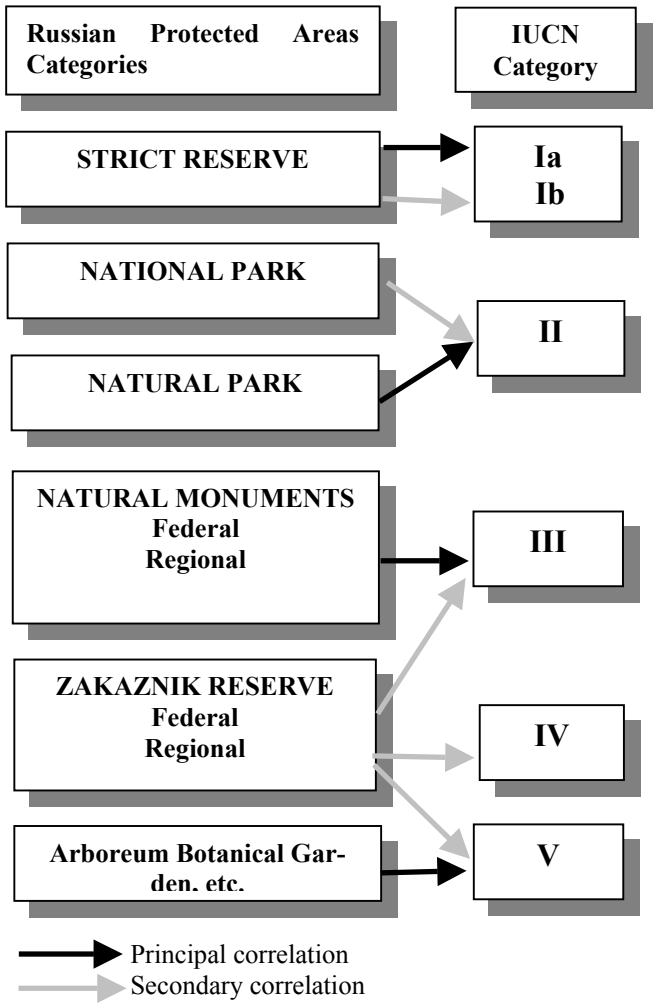
This dramatically changed in the early 1970s and an example of remarkable initiative and progress in systematic selection of protected areas based on biological criteria came from the Regional Meeting on the Creation of a Coordinated System of National Parks and Reserves in Eastern Africa in 1974 (IUCN 1976). The document shows the emergence of a true network of protected areas in nine states of Eastern Africa. At the time, that was probably the most comprehensive protected areas "system" in any of the developing regions worldwide. Still, the document states: "In the past the survival of indigenous ecosystems has in some occasions occurred in areas, which have remained undeveloped through historical accident or owing to the existence of serious obstacles to development. Many such areas have been included in national parks and reserves but most commonly in those areas where the community has included spectacular wildlife or scenery. In some cases, national parks and reserves have been specifically established for the protection of individual species or communities of special interest. Thus, while some biotic communities have been given protection fortuitously and others by design, as yet there has been no deliberate action or policy to ensure the survival of all known "habitats"[1]. The need to initiate such a policy is very urgent. Some ecosystems remain totally unprotected". The document analyses which biomes were not or underrepresented in protected areas – e.g. mangroves, fresh lakes, flood-plain grasslands, subdeserts, etc. – and recommends their preservation in protected areas.

In most countries in South America, protected areas and national parks were few and far between before the 1970s, but since then, numerous protected areas were created, particularly under the inspiration of aforementioned initiatives of the FAO and its criteria. In Central America, most areas were created since the 1980s, when the role of the FAO in biodiversity conservation had waned, and many areas were created in absence of clearly defined criteria (Vreugdenhil 1992, 1996, 1997, Ugalde pers. Com., Inser, pers. com.).

The Soviet Union started developing a system of reserves already In the 1930s. Originally, the system was particularly focussed on the conservation of unique ecosystems, and many of those became protected. Then, the system changed considerably as many reserves were degazetted, but later a number of them were re-instated and new ones were added. Over the past 20 years, a new process of gazetting of additional reserves has taken place, through which not only unique but also many characteristic or representative ecosystems were added. Particularly over the last decade, Russia has used an integrated ecosystem approach to create a comprehensive representative protected areas system for the entire nation. In spite of the bureaucratic procedures required for expanding the system, Russia is one of the few countries in the world that has worked toward a system of protected areas systematically selected based on ecosystem criteria.

[1] The CBD defines (see Annex 1) habitats as the place or type of site where a species or population naturally occurs. Many authors used the term in the sense of the convention's definition of ecosystem. When inconsistent use is quoted, the term is written between parentheses.

**Flowchart 1: Russian Protected Areas Categories**




### 1.2.3. The CBD on biological criteria

While assuming that conserving biodiversity in protected areas systems is the most efficient way to reach the goal of the convention, the big question remains: how does one identify biodiversity? Should one identify all species of a country? If making complete inventories would be feasible, then how should one select protected area, to coincide with the presence of all the species of a country? To do so, one must also know the geographical distributions of each individual species, which is impossible, given the fact that the majority of species is probably still unknown to science. The CBD deals with the selection of biodiversity as follows:

"**Article 7. Identification and Monitoring**

Each Contracting Party shall, as far as possible and as appropriate, in particular for the purposes of Articles 8 to 10:

- Identify components of biological diversity important for its conservation and sustainable use having regard to the indicative list of categories set down in Annex I;
- Monitor, through sampling and other techniques, the components of biological diversity identified pursuant to subparagraph (a) above, paying particular attention to those requiring urgent conservation measures and those which offer the greatest potential for sustainable use;
- Identify processes and categories of activities which have or are likely to have significant adverse impacts on the conservation and sustainable use of biological diversity, and monitor their effects through sampling and other techniques; and
- Maintain and organize, by any mechanism data, derived from identification and monitoring activities pursuant to subparagraphs (a), (b) and (c) above."

It is interesting to see that the CBD combines identification and monitoring. It clearly links the two. Once a Party to the Convention knows what its biological resources are, it should have an idea how successful it is at maintaining a viable representation. Following the logic of the Convention, it makes very good sense to design a methodology for the monitoring that builds on the "identification" phase.

Although the FAO had been a remarkable catalyst in the advancement of the creation of protected areas and nascent protected areas systems in the 1970s, it suffered from important institutional and financial limitations. The FAO is primarily constituted to advice recipient institutions; equipment and the construction of infrastructure could primarily be provided in support of project activities and some field studies. Staff, field equipment and infrastructure had to be counterpart contributions from mostly governments scrambling to feed, educate and provide basic health to their people. It has become a very populist but unreasonable accusation that governments have failed to protect areas after they were created under the advice of international financing agencies – (particularly the FAO). The FAO, and since the 1980s a growing number of bi- and multilateral financing institutions, have made a major difference in favour of conservation, putting into place legislation and basic management organisation. Governments all over the world have made great progress in institutionalising protected areas. But it was only a first necessary step. Adequate funding had not come along to meet the advice. Disqualifying governments for not having secured the necessary funding will not solve the problem and neither will the generic transfer of patronage from central governments to non-government organisations and local communities. If the funding is not there, neither governments nor NGOs will be able to adequately administer the areas.

***Ex-situ* conservation**

Complementary to *in situ* conservation, the Convention also deals with *ex situ* conservation (Glowka et al. 1994). The CBD defines "Ex-situ conservation" as the conservation of components of biological diversity outside their natural habitats. The convention reads:

**Article 9. Ex-situ Conservation**

**"**Each Contracting Party shall, as far as possible and as appropriate, and predominantly for the purpose of complementing in-situ measures:

- Adopt measures for the ex-situ conservation of components of biological diversity, preferably in the country of origin of such components;

- Establish and maintain facilities for ex-situ conservation of and research on plants, animals and micro-organisms, preferably in the country of origin of genetic resources;
- Adopt measures for the recovery and rehabilitation of threatened species and for their reintroduction into their natural habitats under appropriate conditions;
- Regulate and manage collection of biological resources from natural 'habitats' for ex-situ conservation purposes so as not to threaten ecosystems and in-situ populations of species, except where special temporary ex-situ measures are required under subparagraph (c) above;
- Cooperate in providing financial and other support for ex-situ conservation outlined in subparagraphs (a) to (d) above and in the establishment and maintenance of ex-situ conservation facilities in developing countries."

This document shall only marginally deal with *ex situ* conservation, where measures are considered essential complements to *in situ* conservation. The "Botanical Gardens Conservation Strategy" and the "World Zoo Conservation Strategy" and other references support a notion of a more comprehensive approach to this article of the Convention.

## 1.3. OBJECTIVE AND SUPPORTING STUDIES

The targets set by the CBD and the Bali Declaration are ambitious and leave significant room for widely varying interpretation. Glowka (1994) gives suggestions for the identification of species for selecting biodiversity to protected areas, but are they applicable? Can species be identified and mapped? The CBD requires the inclusion of ecosystems to protected areas systems, but can those be mapped? These are essential conditions for the composition of national protected areas systems.

For at least the next decade or two, many countries in the world will not be able to finance the costs of their biodiversity conservation commitments and dependency on scarce external funding will require extreme cost efficiency of protected areas systems, which requires very efficient selection of as many species and ecosystems on as little space as possible, while still providing them durable viability. Considering that:

- Natural ecosystems are shrinking rapidly everywhere, giving way to growing needs for socio-economic land-use, while many species disappear in the process;
- The number of species on the earth is too high to be identified in time for selection to protected areas systems;
- For their compliance with the convention on biodiversity, most countries in the world lack adequate funding to carry out their commitment stemming from the CBD and will depend on scarce external funding;
- *In situ* conservation systems remain under threat of loss of natural ecosystems;
- a representative selection of species and ecosystems needs to be selected to protected areas systems in such a way that they occupy as little space as possible while maintaining a good chance of survival;

**An independent taskforce of experienced conservationists/scientists** have joined forces to elaborate and publish a the methods required to efficiently select as many species and ecosystems in protected areas for there durable conservation.Methods and tools for selection should:

- Be applicable within a foreseeable time, at manageable cost;
- Allow maximum involvement of national conservation scientists by applying appropriate techniques;
- Involve selection procedures that are transparent also for interested non-professionals and politicians;
- Be reproducible;
- Broadly acceptable to the conservation community through transparency and manageability;
- Provide insight in the financial consequences of selection;
- Facilitate affordable monitoring with options of immediate response to acute threats.

The V$^{th}$ World Parks Congress to be held in Durban, South Africa, September 8-17 2003, will be the first congress since the CBD and its related GEF-funding, which have been the dominating instruments in biodiversity conservation over the past decade. The upcoming event will be very opportune to present appropriate technology based tools and methods for complying with Articles 7 and 8 of the convention as they specifically deal with the biological aspects of the convention. The objective of this study is to present methods and tools to:

- Efficiently identify and map biodiversity using proxy identification techniques;
- Design rational protected areas systems on the basis of thus identified and mapped biodiversity, including cost estimates;
- Sustainably monitor biodiversity and protected areas of such systems with in-house personnel of protected areas administrations and collaborative programmes.

The document has been made available to the Vth World Parks Congress on various media, inter alia through web publication: http://www.birdlist.org/nature_management/national_parks/national_parks_planning&monitoring.pdf.

Three seemingly unrelated projects have each contributed to the development and testing of different biological information based ready-to-use methods and tools for the development of protected areas systems, and together they deal with the heart of the CBD (1) **identification**, (2) **monitoring** and (3) **systems of protected areas**:

- The World Bank/CCAD/Netherlands Government project "Map of the Ecosystems of Central Amer-

ica" facilitated the testing of detailed appropriate technology based ecosystems mapping carried out by field biologists and the development of a user-friendly ecosystems monitoring database;
- The COHDEFOR/World Bank/UNDP/GEF policy development on "Monitoring and Evaluation of The National System of Protected Areas and Biological Corridor of Honduras" facilitated the expansion of the Ecosystems mapping database for the monitoring of ecosystems and protected areas.
- The COHDEFOR/World Bank/UNDP/GEF study on the "Rationalisation of the Protected Areas System of Honduras" enhanced a user-friendly protected areas evaluation and financing planning tool "MICOSYS";

The document builds specifically on aforementioned three case studies, but many other studies preceded these projects and the method presented here are the result of about more than a decade of development and testing as may be learned from the cited literature. The document can be read by itself, although the following downloadable documents and programmes form an integral part of it:

- Map Of The Ecosystems Of Central America, Final Report, Volume I, (Vreugdenhil, D., Meerman, J., Meyrat, A.K., Gómez, L.D., Graham, D. J. 2002, http://www.birdlist.org/downloads/cam/ecosystemmappfiles/Ecosystems_Map_Central_America.pdf );
- Rationalisation of the Protected Areas System of Honduras, Volume 1: Main Study, (Vreugdenhil, D., House, P.R. Cerrato, C.A., Martínez, R.A., Pereira, A.C. 2002, http://www.birdlist.org/cam/honduras/Rationalisation_Vol_1_Main_Study.pdf);
- Rationalisation of the Protected Areas System of Honduras, Volume II: Biodiversity of Honduras, (House, R.A., Cerrato, C.A., Vreugdenhil, D. 2002, http://www.birdlist.org/cam/honduras/Rationalisation_Vol_2_Biodiversity.pdf);
- MICOSYS, Application Honduras "National Parks Model", Evaluation spreadsheet in MS Excel, (version 3, 2002, designed by D. Vreugdenhil with contributions by P. R. House 2002, http://www.birdlist.org/nature_management/national_parks/micosys.zip);
- The Ecosystems Monitoring Database, Version 4, Database in MS Access, (designed by D. Vreugdenhil with technical support from R. Mateus, and J. Gianopoulis 2002, http://www.birdlist.org/nature_management/monitoring/Mon_dbase_version_4_0_eng.zip);
- Ecosystems and Protected Areas Monitoring Database Manual, Edition 4, (Vreugdenhil, D., Meyrat, A.K., House, P.R., Mateus, M.D., Stapf, M., Castillo, J.J., Linarte, C.M. 2003, http://www.birdlist.org/nature_management/monitoring/Mon_dbase_manual_version_4_eng.pdf).

More files were produced in the context of those assignments, but they are less important for the presentation of a general methodology. The electronic tools, "MICOSYS" in MS Excel, the "Ecosystems Monitoring Database" in MS Access, as well as the GIS files of the Map of the Ecosystems of Central America in ArcView shape files are available for public use from the website of the World Institute for Conservation and Environment, http://birdlist.org, and complete file sets are available from the following web pages:

- **Ecosystem mapping**: http://birdlist.org/cam/themes/map_download_page.htm
- **Monitoring**: http://birdlist.org/cam/honduras/hn_monitoring.htm
- **Protected Areas System Analysis of Honduras**: http://www.birdlist.org/cam/honduras/hn_parks_study1.htm

Throughout the document figures are presented of parts from the programmes MYCOSIS and the Ecosystems Monitoring Database. The figures cannot be presented in full and for detailed examination of the figures, it is necessary to open the programmes respectively in Excel and Access.

The document offers tools are methods for protected areas design, to be used either in part or in total. They are particularly focussed on biodiversity and cannot function alone. WWF, Netherlands, (A. van Kreveld, pers. com.) emphasises that to be effective, a protected areas system analysis should be carried out in a framework of clear commitment of execution of the findings and integrate the system in a broader socio-economic context, or in its absence, the system risks losing less important areas while the prioritised areas may not benefit. **For an integrated approach, many outstanding documents deal with relevant associated themes. Particularly recommendable are the IUCN Best Practice Protected Area Guidelines Series, to which this document hopes to provide some complementary technical elements.** The series is produced by the World Commission on Protected Areas and particularly No. 1, National System Planning for Protected Areas (Davey 1998) is relevant in this context.

The methods and tools are primarily for countries that require external financial assistance for the establishment of their conservation systems; assuming that the wealthy countries already have elaborate conservation systems in place that have been composed to comprise a broad representation of their biodiversity. As a result, it is somewhat biased towards tropical regions, but many of the principles should work regardless of the region of its application. We are aware that our methods are based on current insights and definitely don't give the ultimate answers to the issues at stake. Therefore, a webpage will be maintained to periodically publish new developments that we consider important in this context. lease first check: http://www.birdlist.org/nature_management/national_parks/national_parks_systems_development.htm

# 2. OPTIONS FOR BIODIVERSITY IDENTIFICATION AND DISTRIBUTION BY PROXI

## 2.1.METHODOLOGICAL OPTIONS

### 2.1.1. The CBD context

The word "system" in paragraph (a) of Article 8 implies that the protected areas of a Party or region should be chosen in a logical way, and together should form a network, in which the various components conserve different portions of biological diversity. It also implies the need for geography-based information (maps) to compose the spaces of areas in the system. Annex I of the CBD is to give guidance to the nature of the components to be identified and monitored by a Party. The latter is to take in consideration the indicative list of biodiversity components presented defined in that annex:

**"**Identification and Monitoring

- Ecosystems and habitats: containing high diversity, large numbers of endemic or threatened species, or wilderness; required by migratory species; of social, economic, cultural or scientific importance; or, which are representative, unique or associated with key evolutionary or other biological processes;
- Species and communities which are: threatened; wild relatives of domesticated or cultivated species; of medicinal, agricultural or other economic value; or social, scientific or cultural importance; or importance for research into the conservation and sustainable use of biological diversity, such as indicator species; and
- Described genomes and genes of social, scientific or economic importance."

The "Identification of components of biological diversity important for its conservation and sustainable use" is an essential element for composing a protected areas system. It requires the identification and finding of species as well as ecosystems (See the definitions of the DBD in Annex 1).

Estimates of global species diversity have varied from 2 million to 50 million (Erwin 1997) species, with an intermediate estimate of 4.9 – 6.6 million (Stork 1997) and a best estimate of somewhere near 10 million (WRI 2003), while only 1.8 million have actually been named (M. Kappelle pers. com.). Scientists have been classifying species for over 200 years, and at present rates of progress, it may take several hundred more years to classify all organisms. It would be highly improbable that a Party could identify all its species of animals, plants and microorganisms within its jurisdiction within a reasonable period of time. However, the speed of loss of natural "habitats" means that information on species is needed now.

To ensure that the conservation needs of the targeted species are addressed, it is necessary to know not only what species exist in a country, but their distribution within the country as well. As the Convention requires that species as well as their ecosystems be protected, it is also essential to identify ecosystems as well as their whereabouts. What makes up an ecosystem, however, is much less defined and agreed upon than what makes up a species. It may be argued that the only complete ecosystem is the biosphere. The CBD defines an ecosystem as: "Ecosystem" means a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit". This definition does not provide sufficient framework for establishing a universally agreed classification system. It may even be argued that ecosystems as functional units don't exist as no place on the biosphere can be defined as a completely isolated system in which all organisms only interact with other organisms within the system.

**Table 1**: Identified and estimated species for different taxa

| Taxon | Identified | Estimated | % Identified |
|---|---|---|---|
| Viruses | 4,000 | 400,000 | 0.01 |
| Bacteria | 4,000 | 1,000,000 | 0.004 |
| Fungi | 72,000 | 1,500,000 | 0.05 |
| Protozoans | 40,000 | 200,000 | 0.2 |
| Algae | 40,000 | 400,000 | 0.1 |
| Plants | 270,000 | 320,000 | 0.84 |
| Nematodes | 25,000 | 400,000 | 0.06 |
| Crustaceans | 40,000 | 150,000 | 0.27 |
| Arachnids | 75,000 | 750,000 | 0.1 |
| Insects | 950,000 | 8,000,000 | 0.12 |
| Mollusks | 70,000 | 200,000 | 0.35 |
| Vertebrates and other close relatives | 45,000 | 50,000 | 0.9 |
| Others | 115,000 | 250,000 | 0.46 |
| Total | 1,750,000 | 13,620,000 | 0.13 |

Source: Global Biodiversity Assessment, United Nations Environment Program (UNEP), 1995

Wherever borders are drawn, there will always be species and processes that in part spill over the edges. Even the earth is not a functional unit, as it needs the sun and the oceans interact with the moon. Still, the Parties to the convention need to stake out territories for their protected areas system, using methods that come as close as possible to differentiating between different ecological conditions, which thus may be considered ecosystems. As many ecological conditions only change very gradually over large distances, differentiation will require the artificial subdivision of differentiating characteristics or modifiers.

### 2.1.2. Potential methods

In order to understand what ideas on identification exist and may be used we have reviewed a variety of methods to select priority sites for conservation, as well as some comprehensive reviews (Bibby 1998; Williams 1998; Anderson 2002; Balmford 2002; IUCN 2002). The diversity of approaches in part reflect the varying conservation goals of the authors. For instance, continent-wide or global goals require much less details than national goals. Special interest goals, such as taxon- or habitat-oriented goals tend to focus on the target taxon or habitat first. As conservation is primarily subject to national legislation, and compliance focuses on all functioning ecosystems with all their, in this document, we focus on criteria for composing comprehensive national protected areas systems that provide shelter efficiently for a representation of all ecosystems and all taxa.

All methods to generate area selection have elements in common. This document attempts to identify identification methods for whose functionality a sound scientific foundation can be argued, can be applied reasonably fast and at manageable costs. Particularly in the tropics, much of our knowledge about individual species is based on a few collections and the challenge has been to develop scientifically acceptable shortcuts to provide the more urgent information needed for biodiversity conservation without classifying and mapping the distribution of every species first (Glowka 1994), and although improvements have been made in the last decade, the situation has not changed much in most countries. Ecological considerations for area selection in the different methods reviewed include: Biologically rich areas, areas of narrow endemism, vulnerability and irreplaceability in a wider context, key populations of selected species or species assemblages, ecosystem representatives and evolutionary processes. Methods being used to identify biodiversity to protected areas can be clustered in three main groups:

a) **"Predicting richness of less-known organisms, by using known patterns of better-known organisms**. (e.g. Bibby et al. 1992). In other words, if an area is very rich in birds, it is probably rich in other forms of life also;
b) **Using rapid assessment techniques to identify the relative biodiversity richness in pre-identified areas**. For example, in one technique, the number of different tree species is counted without identifying the name of each one. Overall species diversity can be predicted from this**"** (Glowka et al. 1994).;
c) **Complementarity technique** (Williams 2001);
d) **Mapping of terrestrial biounits**[2] (IUCN 1976, ABC 1987, DHV 1994) **and water bodies** (Vreugdenhil, 2002) **with distinct assemblages of species on the basis of satellite images and/or aerial photographs and complementary field analysis**.

### 2.1.3. Method a), using distribution patterns of a better known taxon as a proxy for the patterns of all taxa

Originally, Bibby (1992) attempted to use birds as a proxy for the distribution of other taxa primarily on species information, but later, Birdlife International has developed a more integrated variant to the concept, still using birds as primary indicators (Bibby et al. 1992, Stattersfield 1998) to select so called "Important Bird Areas" (IBAs). The BirdLife International IBA Programme is a worldwide project aimed at identifying, monitoring and protecting a network of critical sites for the world's birds and not for other taxa (G. Eken, pers. com). The primary IBA Categories and Criteria (See box 5 for details) are the following (Birdlife International, http://www.birdlife.net 2003):

**Category 1**. Globally Threatened Species
**Category 2**. Restricted-Range-Species[3] (called Endemic Bird Areas EBAs)
**Category 3**. Biome-restricted Assemblage
**Category 4**. Congregations

With this approach, the method of Birdlife international no longer falls under this category, but rather is a multi-criteria selection method to primarily identify areas important for bird conservation.

On a national scale, Wilson et al. (2001) have used amphibians to identify conservation gaps and set priorities for the protected areas system of Honduras. Their study on the distribution of amphibians came up with some very interesting observations for Honduras, but his study was based on more than a decade of research for just one taxon! And there lies another problem: Even if one taxon may serve as a proxy for all taxa, it would still require very thorough and unbiased sampling in many locations with natural communities.

Method a) has been rejected by others, who claim that recent evidence indicates, that no taxon is necessarily a

[2] In literature many terms have been found for geographical units used to denote a geographical unit with distinct ecological, biogeographical and or species composition characteristics. Following ABC, 1997, the term biounit is used, when the precise characteristics of the geographical unit are not specified.

[3] In stead of endemic species, BirdLife International uses the geo-political neutral term restricted-range-species, for which is defines a worldwide distribution of 5,000,000 ha (about the size of Costa Rica) or less (Crosby 1994, ICBP 1992). Endemic species however is such a commonly used term, that we could not avoid using it in this document. We prefer the use of the term restricted-distribution-species to avoid misunderstanding with the use of "range" in the sense as the territory where an individual animal routinely wanders about.

good indicator of the diversity of another, so any prediction needs to be confirmed by on-the-ground studies (Glowka 1994). And yet, areas identified as having unusually high numbers of species of special concern of one taxon often are also found to be important for other taxa and their occurrence often coincides with ecosystems with special ecological characteristics. But full overlap of important sites is not consistently the case. For instance, there are only a few restricted-distribution-species of birds in Central America, but a considerable number of areas with high endemism for other taxa. In general species-based methods usually don't produce homogeneous geographical units or polygons. At best, abundant data may be plotted in – usually coarse – grits.

One must also consider the operational aspects. While quick overviews of a country may be established on the basis of the knowledge of an experienced biologist, in combination with targeted field-data collection, thorough sampling of the taxon of a country, which is required for consistent comparison of areas, is slow and costly. For objectively comparing protected areas and sites with conservation potential, every location must be sampled that may be expected or appears to have different species assemblages. Bird-inventories can be made with considerable detail with the use of mist nets and/or observation in the wild by highly skilled ornithologists. But the method is costly[4] and slow. In many regions of the world, sampling would be needed during at least two seasons, and the window of the optimal sampling season may be restricted. If a hwell-organised team could sample 20 locations per year, and assuming the need for 2 visits to a 100 locations in a country, it would take 10 years to sample the entire country. Further, species inventories or observations primarily provide point or transect locations instead of defined and recognisable areas, although terrain-knowledge of the investigator may be used to stake out the area with conservation potential.

To summarise against the use of taxa as primary proxies[5] for biodiversity distribution to analyse protected areas systems:

- Sampling is rather biased by centres of investigation and access (See e.g. House et al. 2002);
- Difficulties in defining the categorisation of species assemblages as a characteristic class;
- Sampling does not capture seasonal fluctuations, or non-residence status of the recorded species;
- Dependent on extremely intensive fieldwork during at least 2 seasons, while requiring access to inaccessible places involving very time consuming and costly transportation;
- No delineation of territories as required for area selection;
- Costly and highly dependent on the availability of highly skilled taxonomists / birdwatchers / ornithologists.
- Representativeness of one taxon for other ones is at least debated and probably not fully overlapping.

In stead, the data on a specific taxon should primarily be used to verify that the taxon in question is properly represented in the conservation system as a whole.

### 2.1.4. Method (b), rapid assessment techniques to identify the relative biodiversity richness

This method attempts to index biodiversity. These techniques became popular in the mid 1980s. Teams of highly skilled taxonomists visit pre-identified areas – often selected on their likely species richness - to identify as many species as possible during rather brief missions.

In this respect, again birds have been used as indicators. Popular birding sites (which are not the IBAs as defined by Birdlife International) are often used to characterise a site for having high biodiversity. However, popular birding sites tend to be over-sampled and often have been discovered as a result of non-biodiversity related factors. Selecting sites for rapid ecological assessments, based on previous taxonomic information, risks being biased by non-biodiversity related factors such as access and distribution of centres of investigation (House 2002) and thus selected sites risk deepening the sampling bias.

**BOX 1: THE DEVELOPMENT OF A RENOWNED BIRDING SITE**

In the mid 1970s, Limoncocha was intensively studied, among others, by Dr. Dan Tallman. The place was conveniently located in the jungle with daily air-access from the capital, comfortable guest facilities and effective protection organised by the Summer Linguist Institute, whose communication language was English – a very important selection factor for foreign birdwatchers. Once the species list of Limoncocha started to accumulate, it became a must for many birdwatchers on their way to Galapagos. As a result, the list of Limoncocha continued to grow – beyond 600 species – while other areas of much better conservation potential remained in obscurity (Vreugdenhil, pers. observations).

The relative abundance of species in various categories (sometimes called taxic diversity) may also be determined. The categories might include size classes, trophic levels, taxonomic groups, lifeforms, etc. For ex-

[4] Fieldwork is always extremely costly, invariably involving any combination of four-wheel-drive vehicles, motorised canoes, time-consuming stays in the field, air-support to inaccessible areas. This calculation assumes a very optimistic average of 1 week trips, including travel time to the site.

[5] Another commonly found term is "surrogate".

ample, an area with a greater number of closely related species is not as diverse as the same area with the same number of species, which are not closely related, e.g. an island with two species of birds and one species of lizard. This island has greater taxic diversity than the same island with three species of birds and no species of lizard. (Glowka et al. 1994). Ranking biodiversity with such techniques risks overemphasising the importance of one type of ecosystem at the expense of another. Dinerstein et al. (1995) argue against that: "The emphasis on species richness as an indicator of priority ecoregions has skewed interest to tropical moist broadleaf forests and caused us to neglect the diverse ecosystems and biota found in the drier, non-forested or semi forested ecoregions." Fjeldsa (2002) warns that "rain-drenched" areas will need to be complemented by areas along the Pacific slopes of the Andes (which South of Guyaquil, Ecuador, become increasingly dry). Some biounits, like mangroves, paramo grasslands, (Ant-)Arctic tundra and equatorial low open vegetation on sandstone table mountains or Inselbergs are species-poor compared to mixed tropical lowland forests, even if the latter are in heavily intervened condition (A.M. Cleef, pers. com 2001). Neglect or exclusion of such ecosystems on the basis of their biodiversity scores would have very little consequences for the overall biodiversity of, for instance, many of the Andean countries, but it might lead to the exclusion of some highly appreciated ecosystems and organisms from a country's protected areas system. This is not the intention of the CBD.

Besides aforementioned risks, the calculation of a serious biodiversity index would require thorough data-collection very much similar to the methods mentioned under method (a). For plural taxa identification the methodology would require teams of at least 4 or 5 (birds, mammals, plants, herpetofauna and fishes) very highly skilled taxonomists.

The method shares various disadvantages with the previous approach and disadvantages may be summarised as follows:

- Sampling, but rather biased by centres of investigation and access (See e.g. House et al. 2002);
- Difficulties in defining the categorisation of species assemblages as a characteristic class;
- Sampling does not capture seasonal fluctuations or non-residence status of the recorded species;
- Dependent on extremely intensive fieldwork during at least 2 seasons, while requiring access to inaccessible places involving very time consuming and costly transportation;
- No delineation of territories as required for conservation;
- Costly and highly dependent on the availability of highly skilled taxonomists;
- Favours highly diverse ecosystems while it strongly discriminates against highly dynamic and specialised ecosystems.

### 2.1.5. Method c: complementarity technique.

Complementarity is a biodiversity assessment technique often used together with species richness analysis. Representing as much biodiversity as possible in a limited area of land available for conservation constitutes the main principle of complementarity (Williams 2001). The complementarity method aims to ensure a desired level of representativeness by first selecting irreplaceable areas with unique species records, and then selecting others that complement the species composition of the irreplaceable areas until the total set of areas represent all targeted species or until the targeted land area is reached (Williams et al. 2000, Williams 2001). A complementary richness analysis for Europe has been carried out based on distributions of some plant and vertebrate species. 94% of the targeted 3,143 plant and vertebrate species could be represented within 5% of the entire study area (Williams et al. 2000). A major weakness of the complementarity technique is that, if applied on its own, it often selects areas that are widely scattered and each patch of habitat chosen may be too small to retain viable populations of species. Furthermore, it requires an equal sampling effort for all candidate areas that is hardly the case for large areas in economically developing world (Balmford 2002). With the additional required costs, and the questionable results for developing countries, it is not further considered in this document.

### 2.1.6. Method (d), mapping of terrestrial biounits and water bodies

This method distinguishes assemblages of species on the basis of remotely sensed imagery[6], mappable diagnostic criteria and field samples. Glowka et al. (1994) observe that in species-rich countries, the best way - indeed the only practical way - to conserve biodiversity *in situ* is to protect the natural vegetation rather than to take measures for individual species one by one. At least three internationally, widely accepted sub-continental studies have used biounits to review the completeness and effectiveness of protected areas systems (IUCN 1976, MacKinnon and MacKinnon 1986 a and b, see also Box 2), thus implicitly assuming that those biounits represented different assemblages of species.

[6] Both satellite imagery and aerial photographs are remotely sensed imagery.

**BOX 2: SOME CASES OF THE USE OF BIOUNITS FOR BIODIVERSITY SELECTION**

The Regional Meeting on the Creation of a Coordinated System of National Parks and Reserves in Eastern Africa, IUCN, (1976) is the first document that was found in the context of this study that motivates the choice of a specific classification methodology for the composition of a protected areas system based on a physiognomic-floristic ecosystem classification system: "A review of the state of conservation of the biotic communities of a region necessitates the adoption of a practical scheme of classification. As yet none exists which portrays adequately the full range of diversity of ecosystems, and the construction of a comprehensive scheme presents almost insuperable difficulties. For practical purposes, our classification has to be based on major "vegetation types characterised by a combination of physiognomic and floristic features (mainly dominant tree and shrub species and genera)." … "thus while some biotic communities have been given protection fortuitously and others by resign, as yet there has been no deliberate action or policy to ensure the survival of all known "habitats". The need to initiate such a policy is very urgent."

Putney and DPNVS (1976) have used the Biotic Provinces of the world (IUCN 1974) as a distinguishing factor between areas with conservation potential.

Vreugdenhil (1992) was assigned to "determine if the Costa Rican System of National Parks and Protected Areas contains representative and viable ecosystems and if they are being adequately protected". In Costa Rica he found the vegetation map of Gómez (1986), with a level of detail of 54 different ecosystems for the country. The map was based on aerial photographs (L.D. Gómez, pers. com.). Without explicitly analysing whether or not vegetation classes would represent distinct assemblages of species, Vreugdenhil (1992) implicitly used the vegetation map as a method to distinguish different assemblages of species.

Dinerstein et al. (1995) state that "One of the major stumbling blocks to creating a rigorous framework (…) has been the absence of a widely accepted classification scheme of biogeographic units." They further opiniate that their lowest-level biounits, the 'ecoregions', are biologically distinct to some degree, particularly at the level of species and species assemblages".

Aforementioned studies by MacKinnon and MacKinnon (1986a and 1986b) covered both the Indo-Malayan and the Afrotropical realms. Both reviews are based on the work of Udvardy (1975), combined with - where existing - national vegetation maps. In its "Protected Areas Systems Review of the Indo-Malayan Realm, ABC" (1997) [this second review of that region was lead by J. MacKinnon] considers that "Most safeguarding of the region's biodiversity relies on the development of protected 'habitats' selected to protect viable examples of all major ecosystems and hence conserve populations of most of the region's living species". The main objective of the study was to examine the changes to the system of protected areas of the Indo-Malayan Realm over a 10-year period with a view to:

- evaluating the representative coverage and conservation importance of the existing protected areas system;
- identifying gaps and shortcomings in the existing system;
- identifying sites of global priority for conservation; and
- monitoring progress on the development of protected areas within the Realm.

As in the first review, the biounits in the study stem from (Udvardy 1975), with added detail from physiognomic criteria ; the study uses these biounits to geographically identify different assemblages of species.

Grossman (1998) states that ecological communities have been used for many years by TNC and the US Natural Heritage Programmes to help prioritize conservation action. The conservation of many species, both rare and common, is dependent upon the protection of intact community occurrences and their ecological processes. Thus, in addition to the importance of conserving communities in their "own right", their conservation is viewed as a "coarse filter" approach for the conservation of all species, particularly those taxa which are poorly known. The U.S. National Vegetation Classification (USNVC) system has been developed by TNC incrementally over more than twenty years to increase effectiveness of this approach. The USNVC system has emerged from merging the UNESCO classification system with a phytosociological modifiers, attuned to the needs of the USA. Since the development of the system, all previous classifications in the 50 states have or are in the process to become modified to fit the new system. Thus, a slightly modified and expanded Physiognomic-Ecological Classification of Plant Formations of the Earth of UNESCO had become one of the most intensively used systems for presence/gaps analysis applied anywhere before.

From the examples above, it was very clear, that since the nineteen seventies, a worldwide trend was rising to use biounits of some kind or the other as selection parameters for protected areas systems. Such studies have been used in furthering protected areas systems development and in the underpinning of project financing. Their execution requires the identification and spatial demarcation (mapping) of such biounits. Groombridge

(1992) argues that we have "good knowledge of the broad distribution and extent of the world's biomes and the component major ecosystems. Because of their physical characteristics and/or species composition, these large-scale bio-geographical features can be detected and mapped from satellite images and aerial photographs[7]." The question is, whether terrestrial areas and waterbodies can be identified in such a way that they effectively represent distinct assemblages of species.

Until the end of the 1990s, most national or state biounit maps were rather coarse. Since the mid-1990s, applications in several countries of Central America and in all 50 states of the USA have shown that much more detailed distinctions in classification and mapping can be achieved using physiognomic-ecological vegetation classification systems. Those maps have been used for presence/gap analysis (Grossman et al. 1998, Vreugdenhil et al. 2002). Implicitly, the users all have assumed that the biounits they used have distinct assemblages of species, both plants and animals, although this was usually not explicitly stated. Validity of such assumption depends on the classification and mapping methods applied, which requires the review of existing mapping classification systems for the identification of ecosystems and species assemblages.

#### 2.1.7. Overall suitability of options

With this brief review of options, it should be clear that methods (a), (b) and (c) are unsuitable as primary methods for the selection of distinct assemblages of species for protected areas systems, whereas method (d) has potential that will be evaluated further ahead. This does not mean that the information on individual species or taxa should not be used. The relevance will be dealt with under "species of special concern". Species data are important to underpin ecosystem information and indispensable as baseline information for monitoring among other things. But as acquiring taxonomic information is slow, it will have to be collected piecemeal, which is too slow in the context of protected areas system formation.

### 2.2. POTENTIAL ECOSYSTEMS CLASSIFICATION METHODS

#### 2.2.1. Different classification systems

Since the early 1970s, vegetation mapping methods (Holdridge 1971, IUCN 1973, UNESCO 1973, Mueller Dombois and Ellenberg 1974, Küchler and Zonneveld 1988) were being developed that would allow faster and coarser identification than the detailed phytosociological method (Braun Blanquet 1928) of the Zürich-Montpellier School - practiced in species-poor Europe. Originally, often vegetation mapping was based on the drawings of map-sketches on forestry maps and topographic maps. For more realistic mapping, however, vertical views were needed. I.S. Zonneveld (1963, pers. com.) had started out obtaining spatial information of the vegetation of the Biesbosch – a freshwater tidal wetland - by climbing power masts in the 1960s. Later, he pioneered vegetation mapping from aerial photographs and could be considered the initiator of remote sensing techniques for vegetation (and ecosystem) mapping.

Where available, aerial photographs provide detailed information about the physiognomic structure of the vegetation cover, which even can be visualised in stereo from a computer screen after digitisation. On the other hand, photographs also have several disadvantages that are prohibitive for their broad application:

- Very costly to take;
- Too small for conveniently handling large areas (one must handle large numbers of photographs);
- No frequently repeated series available in most countries;
- Difficult to take in heavily clouded regions like the humid tropics and others;
- Need for corrections of each photograph;
- Because of the detail, interpretation is too slow and thus, too costly.
- At times aerial photographs are classified on military grounds[8]

As a result, aerial photographs have not been used on a worldwide scale for detailed mapping of natural vegetation formations.

Until the early 1990s, in most of South America, Africa and Asia, maps with biounits of any kind were very coarse, and – given the state of the available techniques – probably rather speculative (See Dinerstein 1995, MacKinnon and MacKinnon 1986, IUCN 1976). This can at least partially be attributed to the absence of available remotely sensed information. Some good exceptions of vegetation maps exist, and they were based on available aerial photographs (Wright et al. 1959, Gómez 1986). Probably some detailed maps for some countries in Africa were made as well.

More economical – though much coarser – remotely sensed images became available taken from satellites. Although publicly available images have started to be taken since the launching of the satellite ERTS 1 in 1972 (http://rst.gsfc.nasa.gov/Intro/Part2_15.html 2002), it was not until much later that the use of images became available for a broader scientific public. When in the 1970s the FAO carried out its worldwide pro-

[7] This is not correct: bio-geographical characteristics and species composition cannot be detected with or deducted from remotely sensed data, but physiognomic and some ecological data can and it is assumed that the author refers to the latter.

[8] After World War II In the Soviet Union aerial photographs were taken of many parts of the country for military and forestry purposes. However, for conservation planners (ecologists, biologists, geographers) these photographs still often remain classified.

gramme for establishing protected areas systems, the existing techniques for identification of forest cover was still primarily dependent on aerial photographs and field studies by biologists. In those days, many countries lacked national cover by aerial photographs, and often parts of the sets were classified by the military and not available for public use. In 1975 and 1976, in absence of nation-wide recent coverage with aerial photographs, the FAO project in Ecuador spent countless hours of flying over the Amazon region of Ecuador to identify and delineate natural areas which were sketched on paper maps. Also, biological land-cover analysis from aerial photographs – among others pioneered by Zonneveld (pers. com.) at the ITC in Enschede, the Netherlands, – was still a young science, and before the 1980s, probably the vegetation of only few a spots in the world was systematically mapped.

In the early 1990s, the use of satellite images and Geographical Information Systems was not yet widespread in the world of conservation, and much of the worldwide analysis of the world's forest cover was still largely based on aerial photographs (K.D. Singh, pers. com., FAO). This was to change gradually during the decade.

Few GIS and satellite imagery based national study for any tropical country have been found that provided the same level of detail as the ones that were produced in the context of the Ecosystems map for Central America and its predecessors pioneered and produced or with participation by Iremonger (Grossman et al. 1992, Iremonger and Brokaw 1995, Iremonger 1997 with contribution from Vreugdenhil). By 1999, when the project started, the technique had sufficiently matured to allow ecosystem mapping at the scale of 1:250,000, with 30 to more than 60 ecosystem classes in countries, varying in size from 20,000 – 110,000 km2. The project "Africover" (http://www.africover.org/) now appears to have similar levels of resolution.

Experiences from Central America (Vreugdenhil et al. 2002) and Russia have taught us that LANDSAT image interpretation, can be effectively applied at scales 1:300,000-1:100,000, while from both experiences it is concluded that mapping at a scale 1:100,000 is preferred both for the tropics, temperate and boreal conditions, as the costs of the larger scale (more detailed) maps from the same remotely sensed media are about the same. In Russia the correlate with topographic base maps. Aerial photograph interpretation are typically applied at 1:25,000-1:5,000 (Küchler and Zonneveld, 1988).

The different cited studies have implicitly or explicitly combined different elements from various classification methods to describe their biounits (e.g. Grossman et al. 1998, Vreugdenhil et al. 2002). Most of these systems share some attributes, while each system emphasizes certain modifiers(s), such as:

- Phytosociological relations (Plant sociology, Braun Blanquet 1928)
- Biogeographical distribution (Ecoregion approach of Dinerstein et al. 1995)
- Physiognomic characteristics (UNESCO Physiognomic-Ecological Classification of Plant Formations of the Earth, Mueller Dombois and Ellenberg 1974).
- Climatic conditions (Life zones system of Holdridge 1971, 1978)

Vreugdenhil et al. (2002) argue the suitability of the various classification systems, but since the preparation of that document early 2002, a new system has come to the attention, the Land Cover Classification System (LCCS) (Di Gregorio and Jansen, 2000), developed by FAO/UNEP, which now also has been used by the GVM unit of the JRC. Building on aforementioned document (Vreugdenhil et al. 2002), the suitability of different systems are reviewed, with additional reference to the LCCS.

**BOX 3: SOME VEGETATION MAPPING EFFORTS SINCE 1990**

Since 1992, the "DISCover project" in collaboration with inter alia the EROS Data Center, (http://edc.usgs.gov/index.html) and the European Commission's Joint Research Centre (JRC, http://www.jrc.cec.eu.int/) and more than 100 scientists from more that 30 countries, created a worldwide "land cover" map using AVHHR imagery with pixel size 1.1 km, (http://www.ngdc.noaa.gov/seg/globsys/avhrr.shtml#avhrr3). One version has been printed in the Time Atlas of the World (1999). The Times version shows 14 natural classes – including water, snow and ice – which are consistent with the UNESCO classification. Currently (2003), the Global Vegetation Monitoring (GVM) Unit of the JRC broadcasts an updated series of maps on the internet (http://www.gvm.jrc.it/glc2000/productGLC2000.htm) with greater detail.

Dinerstein et al. (1995) consulted GIS-based databases, and used AVHRR satellite imagery, but the resulting maps belonging to the document Conservation Assessment of the Terrestrial Ecoregions of Latin America and the Caribbean are not representing nor showing the actual biounits but the potential zones of the biounits – like the life zone maps of Holdridge. So, if the images were actually used to analyse real cover of the entire continent, this was not reflected on the map accompanying the report.

By 1997, better remotely sensed imagery for evaluating the extent of loss of vegetation cover and indicating trends as well as Geographic Information Systems (GIS) had become more readily available in support of analytical work.

The ABC study considers the data of the boundaries of protected areas and vegetation cover existing for many countries of the Indo-Malaysian Realm in GIS format to be "excellent". However, the applications were still very coarse, and what was qualified as "excellent" by ABC, refers to forest cover maps at scales 1:1,000,000, with a level of detail that varied between 10 and occasionally 20 cover classes (biounits) per country. Most of those countries are very large compared to the countries in Central America, where the level of detail in many cases is above 50 classes; in comparison the ABC maps must be considered very coarse. For the second review of protected areas in the Indo-Malayan Realm (ABC 1997; the team under guidance of John MacKinnon), the region had been divided into five sub-regions, namely Indian sub-continent, Indo-Chinese, Sundaic, Wallacean and Papuasian (Sahul). On the basis of the respective levels of similarity and distinctiveness in species communities, the different sub-regions have been classified into a total of 90 biogeographical sub-units, classed into 24 major biounits. They had been kept as close as possible to the first review in 1986 by MacKinnon and MacKinnon (1986). An alternative classification of the Ecofloristic Zones scheme developed by FAO (1989) had been examined but was not adopted.

The publication of "Atlas of Russia's intact forest landscapes" has detailed maps of the nation's forest ecosystems with detailed descriptions. The Atlas shows that the taiga now only consists of fragments of wilderness, separated by intervened areas.

### 2.2.2. Floristic methods

Aforementioned phytosociological system characterises and distinguishes vegetation units on the basis of mutual affinities among plant species. This requires the collection and comparison of rather detailed plant lists and is very slow in its execution. The system usually describes the vegetation in distinct layers, although this is not mandatory. It allows extraordinary levels of detail; epiphyte communities on arboreous surfaces may be studied as relevé units and described as distinct classes. A typical relevé involves the description of other characteristics as well, such as physiognomy, cover-abundance and age class of individual species. Originally, the application seemed much more focused on the distinction of classes visible in the field than on the mapping, but this changed particularly since the 1960s when topographic maps and aerial photographs became more commonly available (I.S. Zonneveld, pers. com.). At the ITC, Enschede, the Netherlands, the latter has used the Zürich-Montpellier (or Braun Blanquet) system for many years in combination with aerial photographs, which often allows the distinction between several tree species at the same location from their shapes and through indirect observations. Although only some species can be recognised directly from the images, the detailed information on structure, crown shape cover and ecological characteristics such as drainage, seasonality, etc. of aerial photographs often allows the classification of plant associations through deduction. The identification of floristic Zürich-Montpellier classes from LANDSAT imagery with pixel sizes of 30 X 30 m, will usually be limited to the higher echelons in the hierarchy. The system is valuable for monitoring and management purposes in protected areas of forest ecosystems in temperate climates and probably most other formations of the earth. However, in tropical lowland rain forests, the system tends to break down (J.F. Duivenvoorden and A.M. Cleef (pers. com.). For biodiversity mapping focussed on the selection of protected areas systems, the Zürich-Montpellier system can provide the most detailed and most informative biounits of any existing methodology; however, for being so detailed, the system is highly dependent on very experienced taxonomists and highly time-consuming both in the field and in post-field analysis, and therefore, it is too expensive, particularly in the species-rich tropics.

### 2.2.3. Life Zones method

The Life Zones classification of Holdridge (1978) primarily works with climatic data, predicting the potential development of certain vegetation types. Holdridge's system consist of a pyramid of cells, each with varying climatic and elevation characteristics. One cell of the Holdridge System (tropical moist forest) encompasses a vast swath of Amazonian forest extending from the base of the Andes to the Atlantic Ocean. Within this swath of territory are some 30,000 species of trees distributed among scores of distinct communities. Clearly the Holdridge System fails to represent this diversity. Vreugdenhil et al. (2002) explain why in their opinion, this system – while useful when first developed – has become outdated. The now broadly available GIS and remotely sensed imagery, allow multi-criteria classification and higher levels of precision. In absence of weather stations in most isolated areas, the data basis for the existing Life Zones maps has been very sketchy for almost all isolated areas – which includes the far majority of the natural areas. For the delineation of the present distribution of natural vegetation, they would always need to be complemented by remotely sensed datasets for delineation. For the design of protected areas systems, biounits distinguished by this system are too unreliable and coarse.

### 2.2.4. Physical classification by Walter

Walter (1954), who distinguishes zonal and azonal vegetation types. With the term zonal, Walter refers to climate zones, as he distinguishes 9 climatic "Zonobiome" or biome zones (Table 2).

**Table 2: Biome Zones with their climates and typical vegetation characteristics. Free after Walter (1954)**

| Biome Zone | Climat | Zonal Vegetation Type |
|---|---|---|
| Equatorial Biome Zone | Humid equatorial climate without distinct seasons | Evergreen tropical rain forest |
| Tropical Biome Zone | Tropical climate with distinct rainy and dry seasons | Tropical deciduous broadleaved forests or Savannahs. |
| Subtropical Biome Zone | Subtropical desert climate | Subtropical desert vegetation |
| Mediterranean Biome Zone | Climate with summer-draught and winter rains, dry to humid | Broadleaved frost-sensitive hardwoods. |
| Warm-temperate Biome Zone | Warm-temperate (oceanic), humid climate | Temperate evergreen forest, moderately frost-resistant |
| Nemoral Biome Zone | Moderate temperate climate with short frost period | Frost-resistant broadleaved deciduous forest |
| Continental Biome Zone | Dry temperate climate with very cold winters | Very frost-resistant steppes to deserts vegetation |
| Boreal/Austral Biome Zone | Cold temperate climate with cool summers | Boreal/Austral coniferous very frost-resistant forests (Taiga) |
| Polar Biome Zone | (Ant-)Arctic polar climate | Tree-less tundra vegetation, mostly with Permafrost soils |

In each Biome Zone, the vegetation would develop to its typical climax condition, the zonal vegetation, unless stress-factors or extreme soil conditions prevent such development, in which case azonal vegetations or pedobiomes occur. The primary physical conditions that distinguish azonal vegetation types from zonal vegetation types are stress-factors, such as unfavourable soils and poor or excessive drainage. This system has not been widely applied, but it is important mentioning since the terms zonal and azonal vegetations are found in literature and refer to the typical climax conditions, respectively sub-climax conditions due to unfavourable ecological circumstances.

### 2.2.5. Biogeography based methods

Biogeography is the science that studies the relationships among the distributions of organisms at present and in the past (Westhoff et al. 1970). On the basis of the recognition that certain plant families only occur in certain parts of the world, the world has been split up into five floral kingdoms, each with a set of characteristic plant families. With increasingly fine mechanisms of distinction, biogeographers have further subdivided those areas, using genera for the next level down and the regions and species for the provinces and lower subdivisions in the hierarchy. By bundling apparent coincidence of distributions among certain species, biogeography provides special information for identifying partially different assemblages of species with a tendency to share distribution ranges, without having to know them all. Hence, biogeographical units may be used as identifiers of distribution by proxy (Vreugdenhil 2002) or surrogates (Faith et al. 2001). With each further subdivision in the system, the number of distinguishing species decreases while the number of overlapping species increases, thus decreasing the degree of overall distinction. Thus, applied Biogeographical areas are valuable potential modifiers. Udvardy (1975) divided the world into eight realms, which were each subdivided into different biomes. Van der Hammen and Cleef (1986) and Van der Hammen and Hooghiemstra (1996, 2001) very convincingly present, respectively review, the latest insights on the origin of the phytogeographical distribution of vascular plant genera in the neotropical Andean forests. It is fascinating to read how paleoecologists can trace back the spreading of families, genera and sometimes even species across the globe, spanning millions of years, using such inconspicuous clues as pollen, shells, imprints of plants, soil composition and nowadays, genetic composition, etc. Paleoecological analysis in mountainous regions works much faster than in lowlands, as it is easier to interpret ecosystem changes along temperature gradients (Cleef, 1979, 1980). Lowland analysis requires a much broader net of systematically organised soil profiles and sediment sections (A.M. Cleef 2003, pers. com.). Particularly in the humid tropics, the distribution of species is much more difficult to define and consequently when staking out biogeographical units one is still likely to see less reliability and geographical precision in present-day distributions in tropical lowlands than in mountain regions (A.M. Cleef and T. van der Hammen, pers. com.).

Prance (1982 in 1989) proposed that during Pleistocene glacial advances, when the climate of the region became drier and cooler, forest became fragmented into "Pleistocene lowland forest refugia" in Central and Northern South America. Independent speciation within those refugia would have lead to a large amount of local endemism, often referred to as "centres of endemism". These proposed refugia are mainly based on the distribution of four woody plant families, Caryocaraceae, Chrysobalanaceae, Dichapetalaceae and Lecythidaceae. Davis et al. (1996), somewhat seem to question this "popular theory", stating "Whether or not they were refugia, the "fact" that centres of endemism

exist for a large number of different organisms has been well established". Yet, there have been suggestions, that these apparent centres of richness are merely well-collected areas". The latter warning must be taken seriously given such findings on endemic species (See 2.3.3) as presented for instance by House et al. (2002). The latter advised extreme caution considering how difficult it is to make any quantitative comparisons on species richness in a botanically relatively well-sampled[9] country like Honduras. If the knowledge about the distribution of all species - including endemic species - is so highly biased by road access and centres of investigation in such small country, sampling bias is very likely to occur in the vastness of the Amazon as well. Vreugdenhil (e.g. 1992, 1997, 2002) has organised or participated in the organisation of the collection of data in most countries in Central America and has seen how lopsided and often fragmentary data sets can be. House et al. (2002) suspect there to be good reason to even doubt the status of a part of the less-conspicuous endemic or limited distribution species, as their distribution ranges just have not yet been discovered. To go from such sketchy information to identify "centres of richness" and "centres of endemism" requires great scientific caution. Other modifiers are likely to capture such situation.

The CBD approaches biodiversity selection on a country-by-country basis. Within a worldwide strategy to seek the greatest possible representation of ecosystems and species, this has a hidden advantage: not only does it deal with the fact that conservation must have a solid legal and management basis, which primarily is dependent on national legislation and national management organisations, but in most cases, the world's division into national territories automatically leads to plural representation of the world's recognised biogeographical regions, including the WWF's "Global 200". Only in some very large countries, like Brasil, Congo, India, Russia, Anglo-America would it be possible to develop a PA system with the omission of one or more entire biogeographical regions. For a national protected areas system composition analysis, biogeographical divisions are not strictly necessary, as detailed ecosystem maps and the selection criteria developed later in this document lead to much more fine-tuned area composition than biogeographical regionalisation while the country based approach de facto serves as a course proxy for biogeographical regions. This is particularly the case if PA systems are spread across a country's entire territory as recommended in Chapter IV. This method is also much more precise than the approach suggested by Prance or the EBAs of Birdlife International. Furthermore, Davis' suggestion that concentrations of endemism and high species diversity would go together is not necessarily the case: in the humid tropics, high endemism is particularly expected at higher elevations of isolated mountains, where biodiversity is much lower than in the surrounding humid tropical lowlands.

**BOX 4: ENDENISM VERSUS SPECIES RICHNESS**

In Honduras, the mountaintop of Mount Celaque has the highest concentration of endemism in the country (House et al. 2002), but certainly not the highest species diversity. Another example Davis (1996) shows a map of the Centres of Plant Diversity in Central America; for Honduras, the Río Platano Biosphere Reserve is listed. House et al. (2002) have analysed that the area has no records of endemic species. They agree with the characterisation of high species diversity for the reserve, mentioned in Davis, but that has nothing to do with its geographical location: It encompasses a variety of low-land tropical ecosystems, which arguably are very rich in species, due to their climatic conditions and connectivity. Interesting enough, the mountain range Nombre de Dios – with Mount Pico Bonito – which combines high diversity with high endemism – is not mentioned. Islands in general are renown for having relatively high endemism but low species diversity. The two phenomena are very distinct and should not be mixed.

Dinerstein at al. (1995) developed a hierarchical classification scheme that divides Latin America and the Caribbean (LAC) into 8 Bioregions, 5 Major Ecosystem Types (METs), 11 Major Habitat Types (MHTs), and 191 ecoregions.

A bioregion is defined as a geographically related assemblage of ecoregions that share a similar biogeographical history and thus have strong affinities at higher taxonomic levels (e.g. genera, families).

A MET is a set of ecoregions that:
a) share comparable ecosystem dynamics([10]*);
b) have similar response characteristics to disturbance (*);
c) exhibit similar degrees of beta diversity (dependent on vast data sets) and
d) require an ecosystem specific conservation approach (*).

The following classes have been identified: Tropical Broadleaf Forests, Conifer/Temperate Broadleaved Forests, Grasslands/Savannahs/shrublands; Xeric Formations; Mangroves.

A MHT is a set of ecoregions that:
a) experience comparable climatic regimes;
b) have similar vegetation structure;

[9] This qualification must be seen in the context; obviously, the sampling of Honduras remains much to be desired.

[10] * marked criteria are not clearly defined or identifiable.

c) display similar spatial patterns of biodiversity (*); and
d) contain flora and fauna with similar guild structures and life histories(*).

The following MHTs have been distinguished for the study region. Tropical Moist Broadleaf Forests; Tropical Dry Broadleaf Forests; Temperate Forests; Tropical and Subtropical Coniferous Forests; Grassland Savannahs and Shrublands; Flooded Grasslands; Montane Grasslands; Mediterranean Scrub; Deserts and Xeric Shrublands, Restingas and Mangroves.

An ecoregion is a geographically distinct assemblage of natural communities that
a) Share a large majority of their species and ecological dynamics [requires large data sets;
b) Share similar environmental conditions; and
c) Interact ecologically in ways that are critical for their long-term persistence (*).

Ecoregions within the same major "habitat" type can be similar in their structure and ecological processes, but they share few species.

When evaluating the suitability of the eco-region classification system of Dinerstein for biodiversity mapping purposes, the following observations should be made. In the definition, the system pretends to lean heavily on biogeographical history, while, in its application, physiognomic criteria clearly play an important role as well. However, the system is not organised in systematical in modifiers that can be clearly be recognised in the field. At the level of the MET, none of the four characteristics as formulated in the definition can be measured objectively and require expert consensus building through workshops. Of the MHT, only the first two criteria may be defined objectively, but one would need a set of properly defined selection criteria. The primary characteristics of the ecoregions as they appear in the definition cannot be measured objectively and analysis of these regions suggest that they are geographically distinct versions of the MHT, which are more than anything else, coarsely separated physiognomic climatic classes. The method is intrinsically weak as it builds on a combination of a set of modifiers consisting of consensus derived versus mappable criteria and a number of poorly defined modifiers. Therefore, it cannot be reproduced or complemented by independent researchers; with poorly defined modifiers, users cannot know the criteria of distinction of the species assemblages. The ecoregions approach has been designed for continental applications at a scale of 1:10,000,000 (D.J. Graham, pers. com). Yet, the map has been very useful for giving a first quick impression to analyse where major gaps occurred at a continental basis, using the available techniques of its time, but for national protected areas system analysis, it is too unspecific.

Each one of the levels of Dinerstein's method has elements that can not be used as a classifier as they are either not defined and/or not readily identifiable in the field or from remotely sensed data. The method must be considered a one-time product that probably cannot be reproduced by other scientists.

The biogeographical focus for demarcating species regionalisation patterns would be the strength of this mapping concept, but the scientific basis for it is weak. Biogeographical distinction should not be derived from consensus building workshops but from field-data showing patterns of distribution variation, and much more work needs to be done to consolidate the foundation of species regionalisation patterns. Usually workshops tend to strive for consensus. However, the results are not always objective and reproducible. They are important for setting criteria for objectives, verification of consistency of application of the agreed rules and joint evaluation of the results. Actual classes, however, should result from objectively identifiable modifiers.

Geographic regionalisation may significantly contribute as an important modifier to a ecosystems classification system that does not have the inherent weaknesses of the methodology applied by Dinerstein. The level of feasible detail is subject to the knowledge about the distribution of families, genera or indicator species for such regionalisation. A system primarily focussing on biogeographical patterns is too coarse for the design of national protected areas systems, but it may serve well to pre-analyse worldwide representation of coarse sets of species, as seems to be applied by the Worldwide Fund for Nature, (WWF, http://www.panda.org/resources/programmes/global200/pages/home.htm 2002).

### 2.2.6. Physiognomy-based classification systems

#### *2.2.6.1. The UNESCO classification system*

The famous drawing of Mount Chimborazo, Mont Blanc and Mount Sulitjema by Alexander von Humboldt probably shows the first scientific attempt of physiognomic zonation related to elevation, clearly distinguishing between forests, shrubland and montane savannah. In 1955, Beard described the plant communities in the vegetation systems for the tropics on the basis of their structure and growth form and identified a number of units he called formations. These are further subdivided into associations or communities according to floristic composition and can occur in more than one vegetation system. By the end of the 1960s, early 1970s applications ranging from forestry exploitation, land-use analysis to nature conservation, all needed descriptions and spatial delineation of vegetation covers. The detailed Zürich-Montpellier method was too slow and required too much taxonomic knowledge from its applicants to work under conditions of high species richness. Several renowned scientists experienced in the application of the Zürich-Montpellier method used their experience in vegetation analysis to design a species independent method that could be universally applied. A variety of physiognomic classification systems has been designed, usually in combination with other modifiers.

The most broadly accepted had become the "Tentative Physiognomic-Ecological Classification of Plant Formations of the Earth", developed under the auspices of the UNESCO. It is a hierarchical classification system designed to compare ecological "habitat". The system combines physiognomic criteria with ecological modifiers. The authors never seem to have had in mind to provide an exhaustive list of possibilities, but rather provide a framework approach, that allows customisation to the broad variability of nature. This intention follows from the often-repeated instruction "Subdivisions possible", making it an extremely flexible and intuitive system. That the system has a sound foundation may be concluded from the fact that several later systems have spun off from the system, most notably the USNVC system in 1998 and the Land Cover Classification System, LCCS of FAO/UNEP in 2000 (Di Gregorio 2000).

Analysis of physiognomic vegetation classification from LANDSAT images (detail of 30 X 30 m pixels for the visible and near-infra-red bands) is possible, but it is largely deductive, as one cannot actually observe the physiognomic structures such as trees and shrubs or their absence. The level of detail of what can be deducted directly from deflexion of light radiation alone is rather limited, but through combination of indirect information, such as elevation levels, terrain patters, seasonal leave-shedding, etc., one may deduct further detail. From field reconnaissance and prior knowledge, such as dominant species of structural classes in certain regions of a country, experienced field biologists may further enhance the level of detail. Detailed analysis depends on substantial field knowledge of the analyst.

As considerable as these limitations may seem, satellite images have great advantages, such as[11]:

- Each image covers a large area;
- The per hectare cost of LANDSAT image has always been lower than that of aerial photographs; since the launching of LANDSAT 7 in 2001, "raw" (Un-processed) satellite images have become very cost effective[12], as they now cost a mere US $475 each (http://edc.usgs.gov/products/satellite.html 2003 pricing);
- A new series of images of the entire earth is taken every 16 days;
- National military institutions can't block out the analysis of regions by prohibition of the distribution of imagery;
- Digital format facilitates frequent change of scale;
- Classification is rapid and digital mapping can be done directly by computer[13], thus speeding up the process and reducing costs.

In areas with homogeneous vegetation structures, physiognomic classification systems show rather little detail, while there is no good knowledge to indicate whether or not more detailed spatial differentiation of species assemblages occur. To partially compensate for this low level of detail, biogeographical criteria should be applied whenever reasonable assumptions for such divisions may be made. In applying such criteria, one must use reason and logic. Rare ecosystems, which would need to be fully included in a protected areas system, may not need further splitting, unless biogeographical regionalisation is clearly present. It would primarily be relevant for the more common and what shall later be defined as "typically large terrestrial ecosystems".

#### 2.2.6.2. The USNVC classification system

There is an obvious limitation to what one may establish by distinguishing between biological communities on the basis of a selection of ecological criteria and structure characterisation of the vegetation. An important limitation of physiognomic characterisation is that it does not work so well in savannah formations that are subject to varying degrees of dynamism. Savannahs that are the result of fluctuating intensities of burning, draught, and grazing may show considerable differentiation in physiognomy, both in space and in time, while the species in the described units may be remarkably similar. The resulting differentiation may lead to over-representation in a protected areas system. On the other hand, large physiognomic units exist – particularly grasslands - which show remarkable differentiation in at least some of the dominant species that cannot be distinguished on the basis of the physiognomic and ecological criteria of the UNESCO system. This may lead to an under-representation.

In order to be able to achieve greater detail, TNC and the USNVC have expanded the UNESCO system for the USA by adding floristic criteria. They added the possibility of subdividing UNESCO classes with plant species as modifiers. For the needs in the USA, they also brought about some modification in the organisation of the physiognomic-ecological classes. While the UNESCO system is perfectly capable to describe vegetation structures in agricultural systems, it has not been used to do so. For instance, a pine plantation forest could be described as a temperate evergreen needle-leaved forest, while a field of potatoes could be classified as an episodical forb community. Distinction between cultural and (semi-) natural communities is important, and the Americans made an explicit distinction between natural, semi-natural and agricultural

[11] This list is not meant to be exhaustive but illustrative.

[12] A set of 37 images for Central America would now only cost $17.575 and regionally purchased could serve all 7 countries of the region.

[13] This is also possible for aerial photographs, but the process is far more elaborate since each photograph must be converted to digitised format and processed individually.

(Grossman et al. 1998) ecosystems. Thus, the USA government and private organisations adapted the UNESCO approach to a physiognomic-ecological-floristic classification system with adequate mapping detail for conservation purposes of that country.

#### 2.2.6.3. The UNESCO system applied in Central America

The UNESCO system as applied in the "Map of the Ecosystems of Central America" has added some primary elements to the original design. It has followed the principle of the USNVC approach to add a few floristic elements where possible for further distinction of classes. This is, of course, a very early attempt and will need lots of future work. Furthermore it has added an eighth formation for water systems. This element too needs further elaboration. Lastly, in a number of occasions it added some biogeographical distinction. Ecologically it added "moderately" drained.

#### 2.2.6.4. The LCCS

Vreugdenhil et al. (2002) recommended the review of the UNESCO classification system to learn from a quarter century of its application and to expand it to a classification system that could include all ecosystems of the earth, including the aquatic ones. Both the USNVC system and the LCCS have made valuable contributions into that direction; the USNVC system by so clearly distinguishing between different degrees of naturalness, and the LCCS by thoroughly organising the diagnostic criteria into a consistent system of classifiers and by redesigning the system for use with GIS systems. A web-version of the LCCS is viewable at: http://www.fao.org/docrep/003/x0596e/x0596e00.htm ; and the software and manual are downloadable from: http://www.lccs-info.org/ . This site also provides training and a discussion forum.

In most systems, the full combination of diagnostic elements describing a class is not considered, as it would lead to too great a list of possibilities to handle. The UNESCO and USNVC have dealt with that issue by providing a mechanism to add classes following a certain hierarchy. One should note that in practice, not all classes are needed, as certain combinations of characteristics seldom or never occur. The developers of the LCCS created a standardised, hierarchical *a priori* – meaning that all classes are pre-defined - classification system for all the land and near-land water-covered areas. The developers identified a collection of "independent diagnostic classifiers" that may characterise any type of land and near-land water system, and organised them in a very consistent and complete hierarchy, allowing for almost any recombination of classifiers. In the first three layers of its hierarchy, the system splits into respectively vegetated/non-vegetated, terrestrial/aquatic and non-natural/(semi-)natural. This leads to an very practical primary organisation of the landscape, in which one merely needs to deepen the category of focus, while the non-focus categories may remain visible but generic.

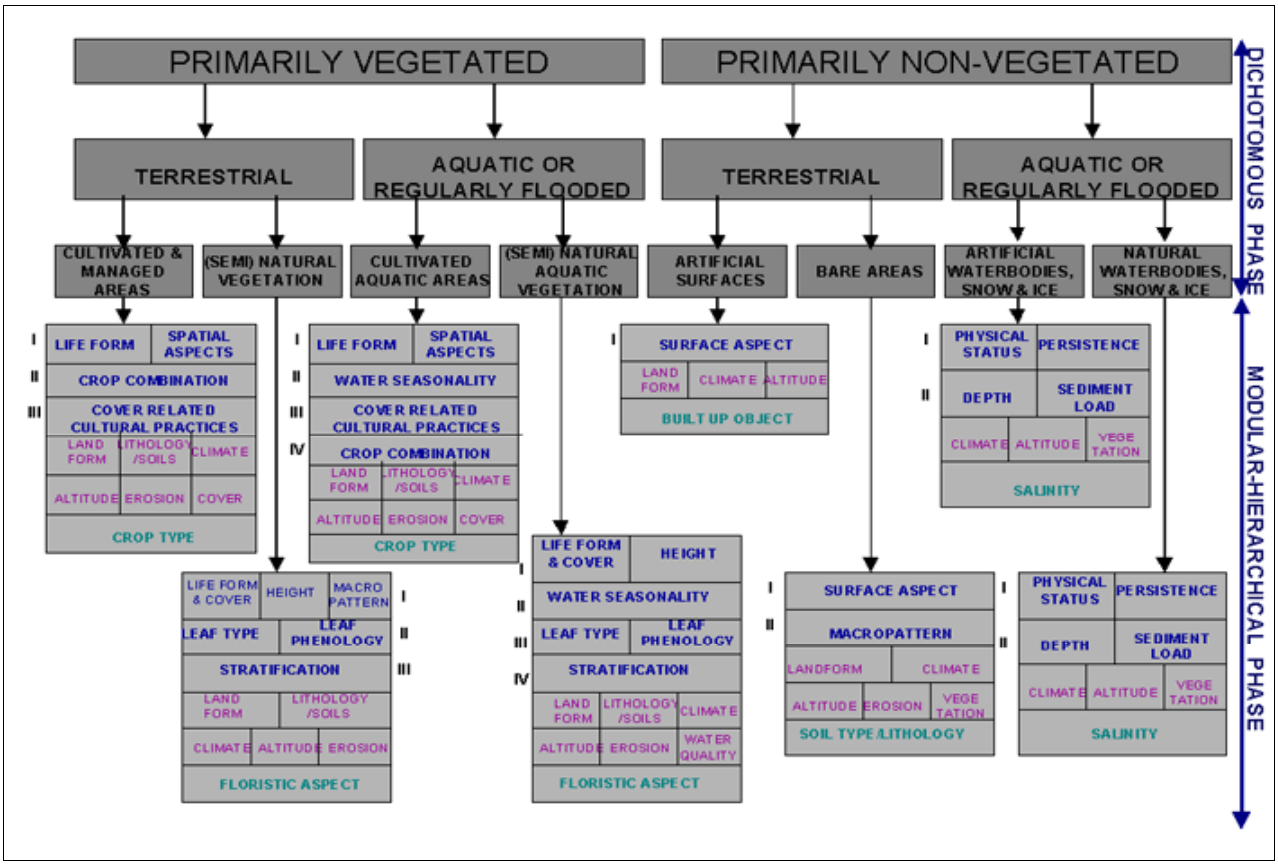



**Figure 1: The LCCS Hierarchy**. The upper classes categorise the system organise the system in: vegetated or not, terrestrial or aquatic and cultivated or natural. From there physiognomic and ecological modifiers allow detailed ecosystem characterisation.

Given the number of classifiers, the total number of classes of the system has become very high, and the system generates its classes using an MS Access-based programme, that generates a Boolean formula, a unique code and a name.

Example "Natural and Semi-Natural Terrestrial Vegetation (A12)":

| Classifiers Used: | Boolean Formula: | Standard Class Name: | Code: |
|---|---|---|---|
| Life Form & Cover | A3A10 | Closed Forest | 20005 |
| Height | A3A10B2 | High Closed Forest | 20006 |
| Spatial Distribution | A3A10B2C1 | Continuous Closed Forest | 20007 |
| Leaf Type | A3A10B2C1D1 | Broadleaved Closed Forest | 20095 |
| Leaf Phenology | A3A10B2C1D1E2 | Broadleaved Deciduous Forest | 20097 |
| 2nd Layer: LF, C, H | A3A10B2C1D1E2F2F5F7G2 | Multi-Layered Broadleaved Deciduous Forest | 20628 |
| 3rd Layer: LF, C, H | A3A10B2C1D1E2F2F5F7G2 F2F5F10G2 | Multi-Layered Broadleaved Deciduous Forest With Emergents | 20630 |

**Figure 2: LCCS codes**. The LCCS names and describes its classes in 4 different ways: listing of modifiers, Boolean formula, Standard Class Name and a code.

Generating the class with a software programme is very nice; the amount of time in the Central America Ecosystem map spent on mere linguistic nomenclature issues has been considerable. A computer-generated classification avoids nomenclature debates as well as coding, consistency and translation problems; a mere push on a button may even generate a nomenclature in a different language!

The developers object that most existing systems (both for vegetation cover and specific features like agriculture) are unable to define the whole range of possible land cover classes. This does not necessarily pose insurmountable drawbacks, as different complementary thematic classification systems may be applied to the same study area. Even the LCCS lives by that philosophy as it states that for bare soil, the soil type can be added according to the FAO/UNESCO Revised Soil Legend. On the other hand, if it is possible to merge several land classes into one system that may be a convenience; care must be taken, however, to not lose the primary focus of a mapping project. By incorporating too many classifiers, the complexity of the data may clutter the information, while printed versions may become illegible. A national thematic ecosystem map needs to distinguish at least some thirty main classes; if it includes different levels of intervention of those classes, the number may more than double. Adding detailed agricultural information to such a map would unduly raise the complexity for the user. Additionally, it is difficult enough to obtain adequate funding for the field of focus of the map, and – depending on the country – it may not be wise to spend limited resources on non-target themes. Thirdly, maps almost always require some level of abstraction, and mapping agricultural information risks applying a wrong category to some kind of field specifically known to a user. Such insignificant error in the context of the main theme may be of great significance to that user, and an overall disqualification of the map may result from non-focus classification errors.

An observation about the nomenclature in the UNESCO system, is pertinent, particularly related to elevation classes. Terms like "alpine", cloud forest, paramo, etc. are not proper names of the modifiers they were intended to represent; at times, this can give rise to heated debates. When applying the system, it may be advisable to substitute such terms by more neutral terms reflecting the modifier. This problem does not arise in the LCCS as it systematically defines each modifier, regardless of the location of its application.

While the LCCS pretends to systematically classify distinct ecological conditions - and it certainly does so more systematically than any other existing system – it still is likely to bunch criteria. The only systematic way of independently classifying each classifier is by creating an independent GIS layer for each characteristic or modifier, and then independently nominate each compound polygon resulting from mutual overlaying. Composing classes in such a way, however, risks the composition of large numbers of very small slightly different polygons that – for protected areas system analysis – may not be considered as distinct ecosystems. Most biologists don't map that way. They produce one map layer to identify polygons with certain homogeny and then classify it, thus implicitly bunching a number of classifiers in each polygon. The LCCS can be used to do that, but it requires some skilled decision-making. Thus applied, the LCCS would still conserve some of its subjective intuitiveness while classifying more systematically than possible with the previously mentioned systems. These issues need to be tested on a detailed case, which has already been mapped with the UNESCO or USNVC method as for Central America.

Ultimately, there is a concern regarding all three systems. Not all classifiers always lead to distinction, or they do so differently under different conditions. For instance, the effects of elevation differentiation in species composition are more pronounced under very moist evergreen forest conditions. Deciduous forests have only one ecosystem zone for the first two levels of humid tropical forest. On the very dry slopes of the Western slopes of the Andes in Peru, one can see how the vegetation cover from being (almost) absent at sea level very gradually becomes denser and higher with increasing elevation, probably accompanied with a similarly slow increase of species. Using the same detail of elevation levels as for humid tropical forests would create an ecosystem differentiation that in reality does not exist. Another case that needs attention in this context is that the changing climatic conditions with elevation on mountains isolated in the landscape, tend to occur more rapidly than on large mountain ranges. This effect was described by van Steenis (1961 and 1972) for Java, who called it "telescope effect" and by Grubb (1971), who referred to it as Massenenhebung. Ecosystem similarity would need to be identified

where both mountain ranges and isolated mountains exist in the same region to be mapped.

The LCCS has made a commendable attempt to include aquatic ecosystems, but in this field, the system needs further work by creating a sliding scale from well-drained terrestrial ecosystems to permanent water systems. Furthermore, under-water aquatic classes, ranging to full oceanic classes, coral reef classes and tidal zone classes need further thought and development. For conservation purposes this is of crucial importance: Conservation programmes must at all cost start integrating the conservation of terrestrial and aquatic areas. One condition for achieving that is by integrating terrestrial and aquatic ecosystems in integrated maps with adequate levels of detail. For aquatic ecosystems, this requires greater detail than currently available in the LCCS. At the bottom of the hierarchy, the system allows further division on the basis of floristic classifiers. At this level, the LCCS is likely to become somewhat subjective, just like the other systems. Whenever people try to organise nature in a human system, they make subjective choices. End-users will always have to deal with that.

With the appearance of the LCCS, the recommendation of Vreugdenhil et al. (2002) to review the UNESCO system has become obsolete; it has solved many of their concerns, but it needs true field testing for detailed mapping and improvement of the aquatic ecosystems. With such a much broader range of options, there is a great need for instructions from an ecologist's point of view what to map and classify - or what not - for natural ecosystems, otherwise, many less-experienced users may get lost in the collection of less useful information for ecological studies. One suspects that similar thematic instructions would be welcome for other disciplines as well.

#### *2.2.6.5. Some words about scale*

Although the developers of the UNESCO classification system at the time suggested a mapping detail of 1:000,000, they had greater levels of detail in mind, for which they laid the basis with classes that would rarely occur on maps of the suggested scale, such as "flushes", "episodical forb communities", "screes", "Lemna-type free floating communities". Vreugdenhil et al. (2002) showed that mapping from printed images at scale 1:250,000 is possible, while M. Carignan (pers. com.) suggested that mapping from LANDSAT imagery is possible at the scale 1:100,000, in which the imagery is the limiting factor, not the classification system. After all, the vegetation structure can be described regardless of scale. Limitations of scale for the application of the UNESCO system and its derivates are subject to the remotely sensed imagery, available funding and contract time, but not to the system itself.

Within the team for Central America, a debate has gone on about the minimum polygon size. Originally, it was set for 150 ha. But then it was found that for some conditions, the size was too small and for others too large. For instance, it may not make sense to map all individual fragments of intact habitat in a largely converted landscape. On the other hand, a miniscule ecosystem on a mountaintop in El Salvador (Vreugdenhil 2002) is extremely important for conservation, as it harbours a unique species assemblage with sub-paramo characteristics. Another example constitutes small isolated rocks sticking out at sea. There may be nothing on top, but under the high waterline, they represent some of the richest marine habitats – pelagic on the Pacific coast and Coralline on the Atlantic coast of Central America. Di Gregorio (2000) suggests the definition and application of variable minimal mappable areas, which would provide a workable solution to deal with the previous issue. The database manual (Vreugdenhil et al. 2003) proposes differentiated minimum sizes for a working scale of 1:250,000.

## 2.3. IDENTIFICATION BY PHYSIOGNOMIC-ECOLOGICAL CLASSIFICATION SYSTEMS

As has been demonstrated in Chapter **2.1**, there seems to be a broad acceptance that geographical biounits of different physiognomy based classes represent – partially - distinct assemblages of species. Burley, (1988), states that "an important concept underlies the [presence/]gap analysis process; by ensuring that vegetation types are well represented in a protected areas system, it is assumed that much if not most of the biological diversity will be protected". The question is whether physiognomic-ecological classes indeed represent partially distinct assemblages species of fauna, flora and fungi as well as ecosystems in the sense of the convention, and whether the analysed classification systems qualify to identify distinct ecosystems and species assemblages.

From the previous analysis, it may be concluded that the UNESCO Physiognomic-Ecological Classification of Plant Formations of the Earth, the USNVC and the LCCS (for the component for (semi) natural vegetation – while very similar in design – are the most comprehensive systems to characterise and classify biounits without requiring advanced knowledge of the underlying species. Of these systems, the oldest, the UNESCO classification system, is the least detailed – lacking a floristic classification modifier and most open water classes. What applies for that system – mutatis mutandis - applies for the other systems as well. Therefore, the analysis departs from that system by reviewing the consequences of its principle modifiers. The other systems are mentioned where they significantly differ and observation are made to where the systems lack potentially useful or important modifiers. In general, for the purpose of selecting ecosystems to protected areas systems, it is recommendable to map an entire country in one seamless GIS, so that comparisons may be made without interpretation differences. For very large countries like Russia, China, India, Australia, Indonesia, Congo, Brazil, USA, such an effort may be difficult to realise both technically and financially, in which case mapping by state equivalent may be targeted.

**Main structural classes**
In most of the cases, the main structural classes of the UNESCO system, Closed Forests, Woodlands, Scrub, Dwarf Scrub, Terrestrial Herbaceous, Deserts and other Scarcely Vegetated Areas, and Aquatic Plant Formation are dominated by distinct species assemblages that thrive primarily in those physiognomic structures. In the USNVC and LCCS, these classes also appear in slightly distinct organisations. An open water category is lacking in both the UNESCO system and the USNVC; the LCCS has a basic modifier for open water classes.

Many trees, forbs, mammals and birds that have a preference for forests are different from those that live in the semi-open spaces of wooded savannahs or the much dryer open grasslands and semi-desserts. At the highest physiognomic level, the differentiation of assemblages of species of flora, fauna and fungi is considerable, although even at this coarse level of categorisation, a number of species can be found in several or all classes present in a study area. Particularly large mammals can be found to roam different in vegetation formations, although their population densities may vary considerably among them. E.g. the Puma, *Pantera concolor*, is spread from North to South America while its habitat includes mountains ranges, forests and plains. But also plant species may span plural UNESCO ecosystems as Duivenvoorden et al. (2001) clearly demonstrate for Amazon lowland forests. The differentiation of species on the basis of vegetation formations (and water systems) does not apply to all species but only to a part of them, thus making structural classes a selection mechanism of **partially** different species assemblages.

By subdividing those structural formations, each resulting level of subdivision is likely to have more species in common among the subdivisions, thus leading to a gradually diminishing differentiation of distinction of species assemblages within a classification hierarchy.

Physiognomic differentiation does not always lead to different species compositions. Ecosystems with considerable variation in dynamics over time – such as wooded savannahs in Africa – may show less floristic variation than one would expect on their structural distinctiveness, as savannahs continuously go through different stages of destruction and recovery, which may be classified distinctly, while the species that belong in those classes remain present in all or most stages of development. Under such conditions, physiognomic distinction may still be relevant for fauna, which has often preferences for specific vegetation structures, rather than for species composition of the vegetation (Den Boer, pers. com., Oindo 2002). Also mangrove systems show strong variation of dynamics in space, which leads to considerable structural variation but very little species variation. Vegetation structures with such considerable overlap of species due to mere temporal and/or spatial development stages of the ecosystem are likely to be found in mosaics. Combined field observations and expert judgement are sometimes necessary to establish to which extent some ecosystems in a country or region must be considered part of a common system and whether or not the development stages must be mapped as separate classes or united into one. If unknown it is better to distinguish them and later decide to treat them as a joint class.

**Climate**
Important as local climate conditions are, the UNESCO system and USNVC only consider broad climatic zones like "tropical" and "temperate", with for instance, all Central American ecosystems defined as "tropical." On a worldwide scale, this obviously leads to completely different sets of species, but within most national maps, climate data are not commonly used as differentiating modifiers. Indirectly, however, both systems reflect local climatic variation as different climatic conditions result in different phytological and phenological expressions of the vegetation, and thereby, those modifiers are important climate-related modifiers as will be shown when reviewed in the following section.

The LCCS uses growing period, moisture and temperature classes. However, the general usefulness of those direct climate data for ecosystem characterisation for nationwide ecosystem differentiation must be questioned for most countries. The first modifier usually varies little on countrywide scales, and the other two, are very crude modifiers, whose quality heavily depends on the distribution of weather stations and the quality and duration of their data series.

Whether occasionally some explicit climatic modifier needs to be added to the other two systems, must be evaluated on a case-by-case basis. Given the characteristics of other available modifiers and the often unreliable quality of available data in remote areas, the need to use of temperature and moisture data for the purpose of detailed biodiversity mapping, requires serious evaluation of the underlying weather data and assessment of the specific necessity for such data. E.g. in the case of the Chocó, the forests would not need to be distinguished from the eastern Andes flanks, as those would be distinguished already on biogeographical grounds, but within the Chocó differentiation on the basis of rainfall may need to be considered if other modifiers could not lead to satisfactory distinction.

**Table 3**: Some characteristics of different methods and classification systems for distinguishing species assemblages[14]

| Evalution criterion/ method | Proxy by Taxon | Rapid Ecological Assessment | Biodiversity Richness Assessment | Life Zones Method | Floristic Zürich-Montpellier Method | Ecoregion Method | UNESCO Method | USNVC | LCCS |
|---|---|---|---|---|---|---|---|---|---|
| **Institution of development** | Various* | Conservation International | Mainly universities | | University of Montpellier | WWF | UNESCO | TNC, USFGDC | FAO, UNEP |
| **Geographical polygonisation** | With abundant data coarse, grit-based polygons may be generated | | No, it mainly analyses equal units | Yes | Point locations, but mapping possible | Yes | Yes | Yes | Yes |
| **Collection duration for national territories** | Fast preliminary identification of prime sites 1-2 years; Data for area comparison 5+ | | Variable** | A few months with availability of climate data | Many decades | A year with availability of biogeographical regions | One year | One year | One year |
| **All taxa Representativeness** | Partially | Possibly | Possibly | Yes | Yes | Yes | Yes | Yes | Yes |
| **Requirements of specialists** | Taxonomists for the taxa under investigation | | | Climatologist | Vegetation taxonomists | Vegetation taxonomists, Paleoecologists | Vegetation ecologists, aquatic ecologists, different taxonomists helpful for providing species baselines. | | |
| **Modifiers** | Species, Species of special concern | | Various factors | Climatic data | Floristic; some physiognomic | climatic, physiognomic | Plural ecological data, including climatic, Floristic if added | Plural ecological data, including climatic, Floristic | Plural ecological data, including climatic, Floristic if added |
| **Effective detail** | High for the studied taxon | High for the studied taxon | High for the studied taxon | Low | Very high | Low | High | High | High |
| **Costs** | Moderate-high** | | High | Low | Very high | Medium | Medium | Medium | Medium |
| **Identification of SSC and endemic species** | Yes | Yes | It may | No | Yes | No | No | No | No |
| **Identification of potential endemism** | Yes | Yes | It may | It may | Yes | It may | It may | It may | It may |
| **Suitability for Protected Areas system presence/gap analysis** | Medium based on large data quantities, but low on superficial data sets | | Low | Low | Low | Medium | High | High | High |
| **Applicability for biological specialists** | High | High | High | Low | Low | Medium | Very High | Very high | Very high |
| **Applicability for junior biologists and non-biologist analysts** | Low | Low | Low | Low | Low | Low | Medium | Medium | High |
| **Universality of application until present** | Worldwide | Worldwide | Worldwide | Latin America | Worldwide | Worldwide | Worldwide | USA | East Africa |
| **Includes water classes** | Depending on taxa used, yes | | Possibly | No | No | No | Component was added for Central America | No | Yes, but needs further elaboration |
| **Restrictions on detail** | Does not apply | Does not apply | Does not apply | Very coarse | Very fine; less suitable for coarse mapping | Very coarse | No | No | No |

[14] * BirdLife Interna-tional, Conserva-tion International, PlantLife, European Union and others. ** Costs subject to objective and required detail

**Elevation levels**

The UNESCO system includes altitudinal modifiers, which are effective proxies for climatic conditions because of the strong relationship between elevation and climate. Ecological conditions vary markedly with changes in elevation. The average temperature of a region decreases with about $0.6^0$ C for every 100m increase in elevation (e.g. Kappelle 1996). Precipitation and humidity usually increase with elevation, although not always consistently. Sometimes rainfall may decrease again above a certain point. What is important, however, that these climatic variations with elevation create very distinct living conditions in which different organisms may live.

Furthermore, tropical regions with humidity deficits at lower elevations, usually undergo a change in degree of seasonality as elevations increase, from deciduous or semi-deciduous to evergreen. Other conditions that change with increased elevation are: lower atmospheric density; increased direct solar radiation, particularly ultraviolet (which may be offset by increased cloudiness); stronger winds; and fewer solar hours because of increased cloud cover. These elevation-related conditions require distinct survival strategies of species such as increased tolerance to *diurnal climate type with low* temperatures during the night, protective layers to reduce ultraviolet exposure, and reduced vegetation height.

The following examples corroborate the variation of species assemblages with elevation. Since 1980 the Amsterdam and Utrecht Universities of the Netherlands and the Universidad Nacional and IGAC of Colombia carried out the Eco-Andes programme (A.M. Cleef, pers. com., e.g. in Cleef 1983, Keizer et al. 2000, Cleef et al. 2003). Within this cooperative research programme, systematic multi-taxa inventories along transects at different elevation levels at 7 locations in the Northern and Central Andes were carried out. Van der Hammen et al (1989) have elaborated a detailed methodology. Currently, the von Humboldt Institute (1999) carries out similar research at 6 locations, more or less evenly distributed from North to South along the eastern flank of the Colombian Andes. This and many other studies elsewhere (e.g. many documents of Kappelle, Islebe and Kappelle 1994) indicate that the flora composition varies greatly along altitudinal gradients. Wilson et al. 2001, finds distinct differentiation along different elevation levels for amphibians in Honduras. It was found, however, that bird distribution varied less distinctly along altitudinal levels than some of the other taxa, and it would make sense that endothermic species are somewhat less sensitive to elevation differentiation and would require fewer ecological distinction in elevation levels. New world monkeys are usually absent above the lowest elevation levels (P.R. House, pers. com.) and make thus part of the species assemblage of the lowest level.

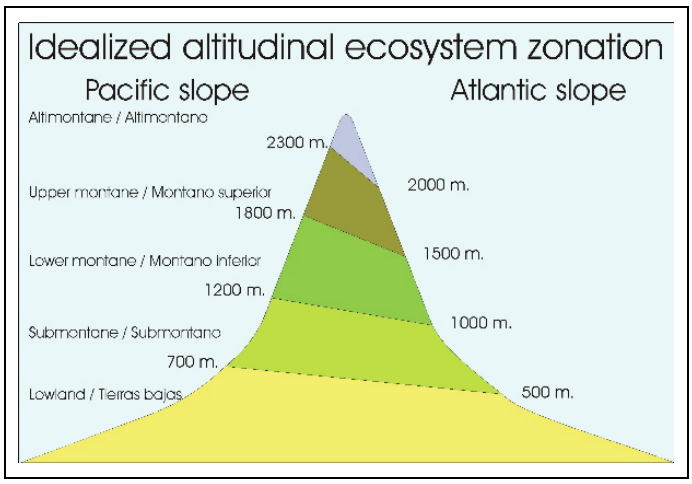



**Figure 3**: Elevation levels of tropical forests in Central America (elevation levels agreed at workshop)

The cooler climate conditions at higher elevation in tropical regions are very distinct from those in the temperate regions. Some of those regions have distinct seasons, such as Central America and Peru, which show pronounced seasonal fluctuations in rainfall, while in the eastern Andes of Southern Colombia and Ecuador seasonality is bearably noticeable. A most critical distinction, however, is that many cool zones along mountain ranges in the tropics never experience freezing conditions. Many coolness tolerant species among those slopes are not likely to tolerate freezing conditions, except those at the highest elevations where occasional cold spells or nightly frost occur. Still, those freezing conditions are different from the ones in the colder climates, where freezing cold seasons set off different processes of reproduction and other elementary phases in life cycles, each genetically built into the residing species.

The UNESCO system defined the following altitudinal descriptors: Lowland, Submontane, Montane, Subalpine, and Cloud. However it did not specify elevation ranges as those vary by geographic region or even depending on exposure to different prevailing climatic conditions along a mountain range. The latter was found to be the case in Central America, where the Pacific slopes are expected to abide by different elevation levels than the Atlantic slopes. It may very well be that in certain regions more elevation levels are needed. Under all circumstances elevation levels need to be region defined, e.g. Vreugdenhil et al. 2002 define respectively submontane between lower limit 500 – 700 and upper-limit 1,000 – 1,200m for Central America, while Prance 1989 suggests 700 – 1,200 and 1,800 – 2,400, respectively for the tropical Andes, while the latter also suggests that for isolated mountains, the elevation levels are very much compressed (e.g. Trinidad and isolated volcanoes in El Salvador and Nicaragua, Vreugdenhil et al. 2002, Meyrat et al. 2002). The elevation scale may be split up in different sizes as well, which implicitly has already been recognised by Mueller Dombois and Ellenberg (1974), where they bundle class B1a, "Drought-deciduous lowland (and submontane) forest" supposedly for being

identical along a greater altitudinal range. Usually, regional differentiation in elevation levels is not considered important for biodiversity distinctiveness within the context of national protected areas system analysis studies, as they usually don't apply within individual countries. In very large countries, however, this may need special attention from the analysers.

**Biogeographical divisions**
Biogeographical divisions don't form explicit parts of any of the UNESCO-classification related systems. As we have seen earlier, however, biogeographical divisions may make additional distinctions of species assemblages, and a biogeographical atlas based on clear indicators can contribute to species assemblages selection. This becomes increasingly important with the size of a country. In absence of such map and where such possibility still exists, equitative distribution of protected areas across a nation will help capture biogeographical distinctiveness on a national scale. Composition of protected areas systems by nation further increases the incorporation of biogeographically distinct species assemblages across the continents even if we don't know their ranges.

**Seasonal change in phenology**
A seasonal change in phenology is caused by partial or full shedding of foliage from the trees and/or by withering or other changes in the herbaceous layer. Seasonality is the result of seasonally unfavourable conditions or stress which many sessile and low mobility species survive by having adapted survival mechanisms to get through the unfavourable season, such as one-year life cycles, surviving underground tissues, seasonal hiding, hibernation, and epidermal or skin desiccation protection. Many mobile species may resort to migrating to other regions or other elevation levels.

Seasonal leaf shedding in the tropics is considered a very important ecological phenomenon, as it reflects seasonal stress, usually caused by draught or flooding. Organisms living under seasonally defoliated trees are more exposed to direct solar radiation and higher temperatures. Assemblages of species that can cope with such seasonal variation are different from those that live under continuously moist conditions. Species that can survive these conditions are clearly distinct from the ones that live permanently under conditions with sufficient moisture to remain evergreen. A note should be made that the LCCS appears to lack a category for evergreen seasonal forest, which maintain evergreen phenology in the tree stratum, but whose herbaceous stratum mostly shrivels (Vreugdenhil et al. 2002) during the unfavourable season. Whether or not seasonal leaf shedding generates considerable micro-climatic differences in temperate and boreal climates is not so clear, but there often the different humus composition from needle leaved (evergreen) or broadleaved (deciduous) forests may create different conditions that may lead to partially different species assemblages.

**Leaf morphology**
The main categories recognised by UNESCO are broadleaved, needle-leaved, microphyllous, palmate, bambusoid, graminoid, and forbs. More than anything, these classes distinguish some of the dominant growth forms, which usually is followed by many of the accompanying species. Predominant leaf morphology may give some information about ecological conditions, particularly in the context of other data. For example, Caribbean Pine, *Pinus caribea*, forests in the tropics are usually more fire resistant, and indicate frequent burning (Vreugdenhil et al. 2002). Most of the time, tropical forests are composed of a mix of trees of diverse leaf types, something which is not further distinguished in the UNESCO classes, but when leaf types can be used for differentiation, this is likely to relate to partial differentiation of species assemblages.

**Drainage**
Drainage is referred to frequently in the UNESCO system. For soil organisms and plants, poor drainage and flooded conditions require sophisticated mechanisms for gas exchange, escape from saturated or flooded conditions, or some form of seasonal dormancy. A huge variety of aquatic and semi-aquatic organisms are adapted to seasonally flooded or poorly drained ecosystems. With drainage being such an important ecological condition, the degree of drainage has been made explicit in the Map of the Ecosystems of Central America. In hilly and mountainous terrain, drainage was assumed good and was not mentioned for higher elevation forest ecosystems. In lowland forest ecosystems, an extra category was added, moderately drained - Grossman (1998) suggests an even further division - to make sure that there would be sufficient species distinction between the well-drained ecosystems in hilly terrain and the periodically waterlogged or drenched systems where species need to resort to special survival mechanisms. Duivenvoorden et al. (2001) quantify that drainage is one of the most explicit factors in differentiation of species assemblages in lowland tropical rainforests in the North-western Amazon.

**Aspect/exposure**
In temperate and subpolar regions, aspect/exposure are important modifiers, which for instance are clearly noticeable at the Pacific Coastal Mountains of British Colombia and the Rocky Mountains (G. Schuerholz, pers.com). These modifiers may be less relevant under tropical conditions, and where relevant, often their effect is restricted to rather small sites, which may fall under the level of detail of mapping or all classes may be found evenly distributed among polygons.

**Soils**
Including soil elements in a classification system would require the involvement of soil specialists and the costs would almost double, which would raise the mapping costs considerably. Particularly in the humid tropics, weathering and leaching may strongly neutralize the effects of the original material, and soil differences are often poorly reflected in the vegetation. At a scale of 1:250,000, soil classes can only be coarsely

distinguished and they contribute little information compared to other ecological factors such as drainage and elevation. When applying GIS at such scale, it may seem very tempting to "overlay" and existing soil map with physiognomic and other ecological modifiers, and thus create a very diverse spectrum of ecological classes. This should not be done, as many soil classes may not reflect distinct assemblages of species.
There are a few broad soil types, however, that are known to be accompanied by specific assemblages of species and which can be valuable in an ecosystem classification. Generally, Vreugdenhil et al. (2002) observed that calcareous soils or rocks provided a sufficient basis for distinguishing ecosystems, and in one case, a soil extraordinarily poor conditions was found to have different clearly distinct. Therefore, calcareous soils are a distinguishing criterion in several classes as well as occasionally "poor or sandy soils" as was the case in one class in Belize. Duivenvoorden et al. (2001) also found some differentiation in species assemblages for different soils in the Western Amazon: Less-poor soils of volcanic origin along rivers in Ecuador and poor white sands in Colombia were found to have notable differentiation in species composition. The latter have been given ample analysis for the Amazon by Prance 1989, where he elaborates "forest on white-sand soil", which, - despite different origins - have in common nutrient poor and excessively well-drained soil conditions, which lead to restricted vegetation cover and dominance of species resistant to stress conditions, and "local endemism". Another soil type is peat. Often formed with *Sphagnum*, peat usually contains very different species assemblages that are tolerant of prolonged waterlogging conditions and often extremely low nutrient contents. H. van der Werff (pers. com.) advised that particularly on a very detailed scale, different a soil variation usually adds a number of additional species to an area, but that requires a level of detail – both in mapping and available soil maps - that usually is not desirable for a national ecosystem map. The need to add soil-based distinction is assessed on professional judgement and edaphological distinction should be applied sparingly to avoid differentiation of non-existing ecosystems.

**Salinity**
Communities with elevated levels of salinity exist primarily, but not exclusively (e.g. Salar de Uyuni in Peru, Great Salt Lake in Utah, saline lakes in Mongolia, Estosha Pan in Namibia, Lake Chany in Western Siberia, etc.
http://visibleearth.nasa.gov/Biosphere/Aquatic_Habitat/Saline_Lakes.html,
http://www.russianconservation.org/ 2002), in coastal environments. Plant species resistant to elevated salt conditions are relatively scarce. In the humid tropics, woody life forms dominate saline coastal environments with mangroves being the most common species. Tropical saline savannah types are less common, and they may still have scattered mangrove trees or bushes. Biodiversity in saline terrestrial and isolated aquatic communities is probably low anywhere in the world, but the species composition is expected to be very distinct from non-saline ecosystems.

**Ecosystem dynamics**
The degree of dynamism is a key ecological characteristic with great impact on species composition and species richness. The higher the level of dynamism, the lower the number of species capable of surviving under those conditions. Usually higher dynamisms is reflected in lower vegetation cover density. Ecosystem dynamism usually is not mapped as such, but it may be intrinsically represented in certain other modifiers. It is an important parameter in an ecosystem relevé (Vreugdenhil et al. 2003). A specific modifier that is based on dynamism is a characterisation of (anthropogenic) disturbance or perturbation, for which three levels have been defined for both terrestrial and aquatic ecosystems in the Ecosystems and Protected Areas Monitoring Database Manual (Vreugdenhil et al. 2003). With regard to the degree of naturalness, it is important to make some essential observations. Many European conservationists and biologists are particularly familiar with landscapes that have developed under centuries of human land-use. Ecosystems formed under conditions without human activity are virtually absent and most nature reserves in Europe protect landscapes that depend on continuous cropping of products (forest, reed, grass, etc.) or reversing of spontaneous developments (spontaneous forestation of heath lands, marshes, etc.). Similarly, many Africa and Asia have developed and are maintained by continuous seasonal burning, usually the result of human actions. Such ecosystems may usually be considered complete when human action continuous. Ancient and non-interfered (virgin) forests ecosystems, however, are not, whether they occur in the tropics or in temperate regions, such forests are different in composition both structurally and in species, from exploited ecosystems and must be mapped and conserved as distinct ecosystems.

High ecosystem dynamism should not be confused with ecosystem stability. Natural dynamism may be a very consistent factor in an ecosystem, such as the continuously changing water table in the tidal zone. Ecosystems under a consistent regimen of dynamism may be considered stable in the context of nature conservation purposes.

**Floristic and faunistic distinction**
It has been argued earlier that for the purpose of mapping ecosystems for the synthesis of protected areas systems, the Zürich-Montpellier system is too labour-intensive, particularly in tropical forests, but its great detail on the basis of distinct species assemblages make it the system with the most detailed distinction of species assemblages known to science. The application of some floristic distinction in the USNVC allow the system to be much more detailed then the UNESCO system, but the same complementary detail may also be added to the UNESCO system, which has been applied to the Map of the Ecosystems of Central America. The LCCS also allows a custom-made lower floristic layer.

Besides floristic distinction, occasionally faunistic distinction is required, as may be the case for certain locations where fauna has a dominant impact or where fauna elements congregate like large colonies of birds, benthic formations (coral reefs, mussel banks) and seasonal migration routs of large ungulates. The floristic layer of the LCCS may be used for that purpose. In general, floristic – and occasionally faunistic – distinction may be used to complement the systems on a need-to-distinguish base, allowing for very detailed species assemblage distinction as needed.

**Scarcely vegetated areas**

Scarcely vegetated areas are found under many different conditions and their species are resilient to the extreme conditions that prevent the development of a closed vegetation cover. These ecosystems have in common that they are low in biodiversity, but the few species they harbour may include highly specialised organisms, some of which are rare, e.g. Sand Bread, (*Pholisma sonorae*, http://www.desertusa.com/magfeb98/dunes/jan_dune2.html 2002), threatened like the Caspian Tern (*Sterma caspia*, UNEP 2002), or just limply liked, like Californian Sea Lion (*zalophus californianus*) by the public at large (Grzimek et al. 1972). They may occur as (fresh water and marine) beaches and dunes that are breeding habitat for some species or water birds and aquatic turtles and they include deserts with highly adapted plant and animal species, such as mammals that can live in the total absence of drinking water, like the Addax, *Addax nasomaculatus*. Other scarcely vegetated areas are tidal mudflats with specialised benthos and feeding wader birds, lava screes and montane screes with "subnival communities" and bare marine rocks with highly concentrated bird colonies.

**Aquatic Ecosystems**

Although the UNESCO system is usually considered to predominantly cover terrestrial formations, it does include vegetated aquatic ecosystems. Within formation classes I-VI terms such as "flooded," "riparian," and "waterlogged," are used to describe ecosystems that are wet or covered with water on a periodic or temporary basis, or even constantly in the case of certain swamp formations. These ecosystems include bogs, flushes, salt marshes, flood savannahs, sedge swamps, and numerous other water dominated ecosystems.

In addition, formation class VII, Aquatic Plant Formations, encompasses systems in which water covers the land constantly or most of the year. This formation class includes five formation subclasses. Each of these subclasses has a distinct assemblage of species that usually occupy different niches of an aquatic ecosystem depending on water clarity, depth, flow velocity, etc. Several formations may occur within a short distance of each other, and in many cases they are not mappable at a scale of 1:250,000 as used in Central America. Vreugdenhil et al. (2002) considered a variety of existing classification systems (including Salm and Clark 1984, Gómez 1984 1986c; Green et al. 2000) but finally they determined that the original UNESCO system categories were adequate to describe aquatic ecosystems with a distinguishable vegetation cover above or under the water surface. The recognised distinct vegetated aquatic classes all have distinct floristic species assemblages. The variation of differentiation of aquatic faunal assemblages may be more determined by some of the physical characteristics.

**Open Water Formations (VIII)**

In order to reach analytical completeness to deal with all biodiversity, an additional class was needed to classify aquatic ecosystems with little or no vegetation cover: "Open Water ", which Vreugdenhil et al. (2002) added as class VIII. These are predominantly covered by water and have less than 10 percent of their area covered by emergent or submerged vegetation. Such class is also needed for the USNVC. The LCCS has a few open water classes, but the system needs more subdivision. The aquatic component of each system needs more elaboration, but with customised identification, sufficient distinction can be established to classify aquatic ecosystems with distinct species assemblages. To further the division of open water systems for Central America, it was determined that salinity was the most important divisive characteristic, primarily using fishes as indicators (Vreugdenhil et al. 2002). Most marine species are separated from limnic (freshwater) species by higher concentrations of salt. Some species are adapted to switching back and forth between saline and freshwater systems. However, the ictiofaunal assemblages for limnic, brackish, and marine systems are partially distinct and the degree of salinity is considered the single most distinctive factor for aquatic ecosystems. In the new formation class, the proposed division is:

- Limnic (freshwater) ecosystems
- Brackish ecosystems
- Marine ecosystems
- Saline lakes and closed seas

**Limnic or freshwater systems**

These are inland systems, typically rivers, lakes, and swamps. Wooded swamps usually fall under Formations I, V, or VII. Lakes often have fringes of emerged vegetation that are classified under formations V or VII. Limnic open water systems lack major areas of aquatic vegetation that would allow their classification under the UNESCO system. It is possible that in the future, fish distribution patterns could provide information to further distinguish limnic open water ecosystem classes. An important physical modifier is the pH level (G. Boere, pers. com.).

**Brackish systems**

This subclass is predominated by estuaries-aquatic systems of varying salinity that usually are highly dynamic. Estuaries – the coastal waters (river mouths and deltas, lakes with permanent or temporary outlets to the sea, "wadden seas", etc.) where fresh water and sea water mix - often have high sedimentation, low transparency, and low species diversity, but high organic productivity. In Central America, most estuarine tidal zones are covered with mangroves (IA5). If the bare

mud flats are extensive enough, they would be classified under category VIB3, "Bare inter-tidal mud flats". A distinction was made on the Map of the Ecosystems of Central America between semi-closed and open estuaries. In retrospect, however, there probably is no clear ecological reason for maintaining this distinction.

**Marine ecosystems**
In the context of this work, marine ecosystems (that is, areas that are below the tidal line and permanently under water) are split into littoral systems (to a depth of 50 meters) and pelagic systems (deeper than 50 meters), but estuaries are excluded. As the term is traditionally used, littoral systems also encompass tidal zones, which may include beaches, salt marshes, and mangroves-ecosystems placed under classes V to VII. Within the littoral zone, sea floors may be rocky, silty, sandy, or gravely. While these characteristics could be used as classification criteria, they were not used at the 1:250,000 scale of the Map of the Ecosystems of Central America. Some areas will have greater than 10 percent vegetation coverage, and therefore, would not be included in class VIII (although in practice, most are so small they cannot be mapped except at fine scales). In particular, areas of seagrass can be classified by us as VIID2a, "Submerged marine fixed forbs." Sessile marine macroalgae often occur among corals (although in coverage, they usually are much less important than corals), and at times, may be important enough to be mapped as VIID2b, "Submerged marine fixed macroalgae". Given examples indicate what a distinct ecosystems with sometimes very different species assemblages may be distinguished in aquatic ecosystems, using rather simple classifiers.

**Bottom composition**
Another factor of distinction is the bottom composition. Some benthic fauna can only live in soft bottoms, while other species require a hard substrate for their attachment. Many mobile fauna species prefer to stay near hard objects like boulders, submerged rockscapes, shipwrecks, etc. particularly if they provide hiding places for escape. Several Salmoids need gravel beds for spawning. Salm and Clark (1984) provide several bottom modifiers that may be used for open water formations. Mumby and Harborne, (1999) provide detailed classes for coralline costs, but at that level of detail, not all coralline classes reflect distinct assemblages of species (Guzmán 1998).

### 2.3.1. From vegetation map to ecosystem map

The UNESCO system related classification variants all allow fairly to rather detailed (depending on the use of floristic elements) classification of biounits with a reasonable degree of geographical consistency. The LCCS will be no doubt the more consistent, but thus far it has not yet received as long as a tradition or application as the other systems. From the previous analysis of modifiers, it may be clear that these classification systems not only provide information that leads to information about the vegetation, but about conditions that determine the suitability of that location to representatives of any taxon, particularly when complemented with additional characteristics when appropriate. From the previous consideration, it may be deducted that different recombinations of modifiers most likely lead to partial different assemblages of species. Particularly by incorporating an aquatic "formation", ecosystems and species assemblages are incorporated that were not considered by the designers of the UNESCO classification system.

Sometimes, specific zoological information can and needs to be mapped, such as the distribution of coral reefs and faunal congregation sites (e.g. breeding, roosting sites). Given the fast developing GIS techniques and affordable satellite images, more and more ecological characteristics may be distinguished and mapped. Thus applied, GIS-based maps, like the Map of the Ecosystems of Central America (Vreugdenhil et al. 2002) that heavily lean on the physiognomy of the most voluminous expression of life, the vegetation, inform us not only about the vegetation structure, but also about spatial differentiation in ecological conditions and related species assemblages between organisms. Biounits thus identified, represent entire ecosystems that can be used as surrogates for the selection of biodiversity and ecosystems for protected areas systems. These units are geographically unbiased as they come from universally sampled data sets collected by satellites and the modifier identification is applied across the entire image of each image identified. Presence/gap analyses on the basis of such datasets must be considered the least biased option with presently available techniques.

The next challenge is to obtain some basic idea about the species assemblages that underlie the different ecosystem classes, and create a baseline of knowledge about the protected areas and life on earth. This requires the systematic collection of species and ecological conditions, particularly in the protected areas. Once a pre-selection through the proxy ecosystems has been made to protected areas systems, the classification of a good proportion of the species of the world becomes more feasible, as taxonomists will get the time to at least classify those species on earth that survive in protected areas systems.

### 2.3.2. Recognition from satellite images

The Map of the Ecosystems of Central America has been drawn from LANDSAT images, partly from printed copies at scale 1:250,000 and partly from computer monitors. The map clearly demonstrates that satellite images are suitable for considerable distinctiveness in ecosystem types, but additional information is needed, most notably elevation levels. Duivenvoorden et al. (2001) have used similar classes[15] and they con-

[15] The study did not use the UNESCO nomenclature, but the classes coincide with the UNESCO system and the level of detail applied in Central America.

clude that “the similarities in the vegetation are reflected in the patterns on the satellite image”. However, only few floristic modifiers may be recognised, such as coniferous versus broadleaved and mangrove forests.

Particularly, lowland tropical rainforest remain problematic. Duivenvoorden et al. (2001) warn that one should be careful when extrapolating inventories to an entire area mapped from a satellite image, as one may suppose that other forest types exist within such area, that have not yet been identified. This uncertainty for lowland tropical rainforests is common to all identification methods, although – if existing, they are likely to be included as subdivisions in the larger ecosystem classes.

Radar imagery has the advantage that they can be taken at any time of the 24-hour day, independent of daylight or cloud-cover. Classification with radar imagery taken from airplanes is possible, which allows processing for stereoscopic viewing (Sader 2001). Quiñones, (2002) has used radar imagery for monitoring purposes, which is particularly valuable in areas of high levels of cloud cover. Radar images taken from airplanes, however, is a costly technique, which in developing countries also may often still require enormous logistic preparations. Satellite radar images are still rather coarse. For a while, in many countries ecosystem mapping will still primarily be dependent on applications from satellite images to which considerable progress is made

### 2.3.3. Database

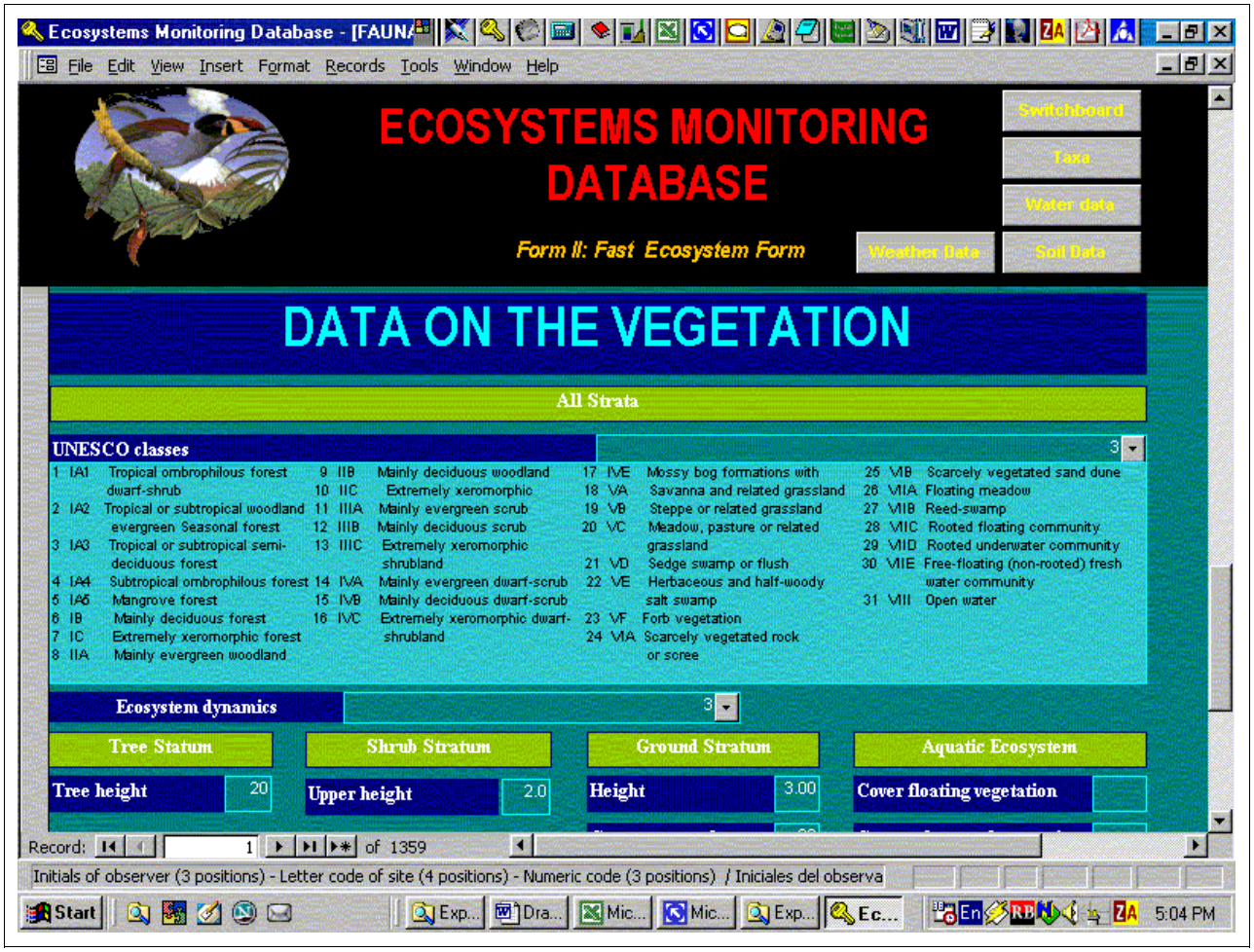



**Figure 4: The Ecosystems Monitoring Database**, which accompanies the Ecosystems Map of Central America. It allows detailed information storage on ecosystems, species and protected areas management. The “Fast Ecosystem Form”, allows quick entries from observations on the fly".

An ecosystem map presents sharply defined polygons with authoritative labels. However, any classification system is arbitrary in the sense that it introduces artificial separations in only gradually changing landscapes by subdividing modifiers in subdivisions agreed by convention and which can often not be located in the field with precision. Polygons reflect all the biases of its authors, as well as all the imperfections and errors inherent to any map and to any classification system (Muchoney et al. 1998, Touber et al. 1989). To compensate for such imperfections, sound field data need to be collected, representing consistent sampling and stored in a logically organised database. The mapping project for Central America dedicated great effort to deciding which field information to collect. It started out with the "STEP" design of the University of Boston (Muchoney et al. 1998) and tested it extensively with the participating scientists in the field. Renowned external international scientists were consulted (Professor R.A.A. Oldeman, Ph.D., University of Wageningen;

Professor A. M. Cleef, Ph.D., University of Amsterdam and Wageningen; Dr. H. van Gils, ITC, Enschede and M. Kappelle, PhD, University of Utrecht). The database allows detailed tracking information, physical data registration that allow characterisation varying from aquatic to desert ecosystems, physiognomic and floristic characterisation as well as detailed soil characterisation and water composition. The data set allows efficient characterisation of any ecosystem type, terrestrial or aquatic. (See further Chapter **5**).

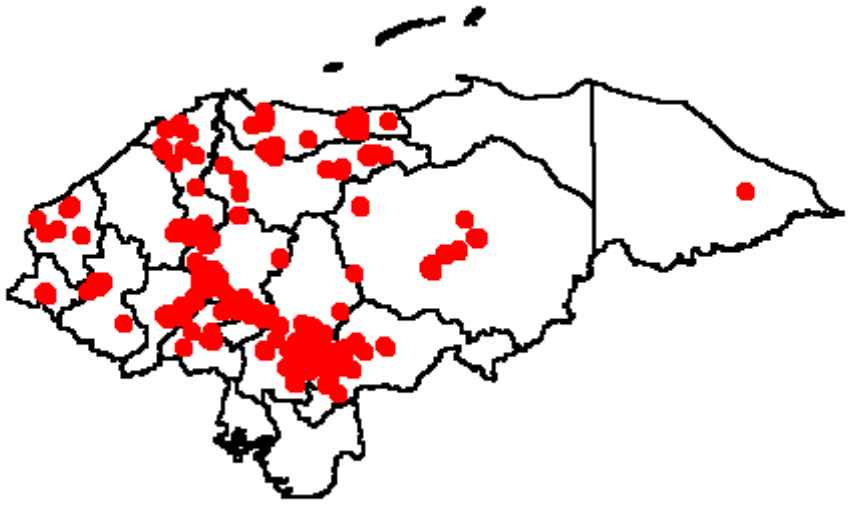
### 2.3.4. The role of species of special concern

With a rich verbatim among conservationists to value the importance of species with conservation concern, such as rare, endangered, threatened, endemic, flag species, keystone species, etc. Vreugdenhil (1992a) united all those species under the term "species of special concern", a term previously, independently used by G. Boere (pers. com).

Commonly advocated as a selection criterion for protected areas are endemic species. In general, using endemic species to select protected areas is somewhat dubious. Small countries like Central America will proportionately have far less endemic species than large countries like Brazil. Even if endemism is used in the sense of restricted-distribution species with a maximum distribution range of less than 5,000,000 ha – about the size of Costa Rica - (Stattersfield 1998, Birdlife International, http://www.birdlife.net/ 2003), the selection of qualifying areas would be extremely coarse, e.g. Honduras, which has about 60 qualifying ecosystems, has no more than a handful of areas with restricted-distribution species of birds and mammals combined (House et al. 2002). The largest protected areas of the country have no endemic species and would not be selected using this criterion. The high arctic has no endemic species at all, while limited distribution species are extremely rare in the entire boreal region (K. de Korte, pers. com.). This can be no argument to neglect polar and sub-polar ecosystems in protected areas systems. In general, typically large ecosystems (see later in this document) would rarely qualify.

House et al. (2002) show convincingly that the known distribution of endemic plant species in Honduras is concentrated around the capital city of Tegucigalpa, which is home to the two largest botanical research institutions in the country and areas along main access roads. Obviously lopsided sampling leads to distorted information on endemic species. In the tropics the mere fact that a species has only been found on a few occasions and/or in a restricted area is actually rare and/or endemic; particularly for small organisms there is too little information to make such categorisation (H. van der Werff, pers. com.).

**Figure 5: Map of plant species endemic to Honduras**



The bias of the data set on endemic plant species of House et al. (2002) are by no means limited to plants; they show from less detailed data sets that a similar situation applies to fauna species and from our collective experiences we have many indications that justify us to suspect that similar situations apply to all countries of the world, including developed countries. Further, geographical sampling biases are not restricted to endemic species, but apply to all species sets that are not collected through specific random sampling site selection. This corroborates our previous conclusion that only data from ecosystem maps are sufficiently

impartial to serve as the primary source of comparison for presence/gap analyses.

This does not mean that information on the distribution of individual species should be neglected in area identification. On the contrary, House et al. 2002, show how species information complements ecosystem information acquired from ecosystem mapping.

Despite the obvious sampling problems associated with endemic species in Honduras, it is possible to learn from the distribution of its restricted-distribution-species. Geographical isolation is considered one of the primary requisites for species development. In Honduras, 6 ecosystems together contain 60% of all of the reported endemic plant species in that country, yet they only represent 12% of the total area of natural ecosystems. Those ecosystems all have in common that they are relatively small and geographically isolated, being either montane or being restricted to isolated dry valleys in a rain shadow. The natural fragmentation of these ecosystems is possibly one of the reasons for the high numbers of species with restricted distributions. Restricted-distribution-species species are absent from aquatic and wetland ecosystems as (1) they have very effective connectivity and (2) they are relatively dynamic, which requires mobility and flexibility of species to survive in those ecosystems.

Also in the montane environment of the Andes, endemism and restricted distribution is much more common. Among higher plants, restricted distribution and endemism is about 15 times higher in the Andes than in the Amazonian lowlands (H. van der Werff, pers. com), while species densities are usually higher. With nearly 9,000 species of vascular plants and ferns, Turkey has the richest flora of any country in the temperate zone, with a level of endemism of almost 34% (3,022 species). New plant species are still being discovered in Turkey at a rate of more than one a week (Özhatay et al. 2003). This is mainly because several mountain ranges extend in the country. Under such circumstances, smaller and more narrowly distinguished ecosystems are required to distinguish different species assemblages. There, proven high endemism (or rather restricted-distribution species) may help distinguish between different ecosystems.

In Honduras, endemic species in aquatic and wetland ecosystems are absent as they have very effective connectivity, and usually, they are relatively dynamic, which requires mobility and flexibility of their species to survive[16]. In general, typically large ecosystems are likely to have few endemic or limited distribution species. Pitman et al. (1999) studied the distribution of trees in the Department of Madre de Dios in Peru, where they did not find endemic tree species, but most species occurred in very low densities and species diversity was extremely high. Thus the absence of endemic species, provides no indication about the degree of biodiversity and should not be used as a proxy ecosystem evaluation or weighting.

In the case of sites with very restricted seasonal use by congregational animals, protection may be provided through protective measure during the season of intensive use. This may apply to breeding colonies of birds and locations where birds congregate during migration, etc. Examples of other taxa with migrant populations or congregarious behaviour include most Pinnidea (Seals, Sea Lions and Walrus), Cetacea (Whales, Dolphis and Porpoises), all Chelonidae (Marine Turtles), some butterfly species – e.g. the Monarch butterfly, *Danaus plexippus*, (Bohdanow 2002) - and some ungulates, such as the Caribou, *Rangifer tarandus,* in the Neoarctic, the Mongolian Gazelle, *Procapra gutturosa*, (MNE 1997) in Northern China and Southern Mongolia, and the Wildebeest, *Connochaetus taurinus*, in Eastern Africa (Nowak 1999). Areas falling under these criteria should be mapped within the context of ecosystem mapping and classified as distinct classes with the faunistic element as modifier.

When available, species distribution sets can provide valuable complimentary ecosystem information, and often at least a basic set on the distribution of birds is available. A practical problem in using species for distribution analysis is that many data that have been collected belong to individual scientists or institutions, many of which don't have a policy of openly and broadly sharing their scientific data; as a result, such data – although collected – are not available to other researchers or conservation institutions. This is regrettable; more so, because public funding derived from tax revenues ultimately has financed most of the collection of those data. **Bi- and multi-lateral financing institutions should adopt a policy to always include a clause in all financing contracts that the beneficiary shall deliver all data resulting from that financing to the financing institution to be made available for public use.**

[16] Worldwide a number of aquatic species have 'beaten" the odds and survived climatic change in extremely isolated desert habitats (Chen, 2002), deprived of all connectivity.

**BOX 5: IBA CATEGORIES AND CRITERIA**[17]

Birdlife International, a global union of ornithological and bird conservation organisations has defined 4 categories of "Important Bird Area" for selecting globally important areas for the conservation of birds, which are listed as follows (Fishpool & Evans 2001).

**Category 1. Threatened Species**
Criterion: The site regularly holds significant numbers of a globally threatened species, or other species of global conservation concern.

A site qualifies under this category if it is known, estimated or thought to hold a population of a species categorised as Critical or Endangered.

Population-size thresholds for those species identified as Vulnerable, Conservation Dependent, Data Deficient and Near Threatened (Birdlife Internatioanal 2000 and Collar et al. 1994) are set regionally, as appropriate, to help in site selection.

The words 'regular' and 'significant' in the criterion definition are to ensure that instances of vagrancy, marginal occurrence, ancient historical records etc are excluded. Sites may be included, however, where the species' occurrence is seasonal (or at which it solely present at more extended intervals if suitable conditions prevail only episodically, e.g. temporary wetlands). E.g.: the Great Bustard Otis tarda is a globally threatened species found on several continents. There are additional regional and sub-regional criteria in Europe and in EU countries for threatened species populations. Such criteria may also be developed for other regions.

**Category 2. Restricted-distribution-Species**
Criterion: The site is known or thought to hold a significant component of a group of species whose breeding distributions define an Endemic Bird Area or Secondary Area.

Endemic Bird Areas (EBAs) are defined as places where two or more species of restricted distribution, i.e. with world distributions of less than 5,000,000 ha, occur together (Crosby 1994, ICBP 1992 and Statterfield et al. 1998). Also included here are species of Secondary Areas. A Secondary Area supports one or more restricted-range species, but does not qualify as an EBA because, usually, only one species is entirely confined to it.

For many EBAs, which hold a large number of restricted-range species, it is necessary that a network of sites be chosen, by complementarity analysis, to protect adequately all relevant species. The "significant component" term in the criterion is intended to avoid selecting sites solely on the presence of one or more restricted distribution species that are common and adaptable within the EBA and, therefore, occur at other chosen sites. Additional sites may, however, need to be chosen for one or a few species that would otherwise be under-represented. E.g.: the Toucan Barbet, Semnornis ramphastinus is a restricted distribution species found in the Chaco Region of the West Andes. Mindo, in Ecuador is one of the key sites for this species

**Category 3. Biome-restricted Assemblages**
Criterion: The site is known or thought to hold a significant component of the group of species whose distributions are largely or wholly confined to one biome.

This category applies to groups of species with largely shared distributions of greater than 5,000,000 ha, which occur mostly or wholly within all or part of a particular biome and are, therefore, of global importance. Many of these assemblages occur in places - deserts etc. - where delimiting IBAs is particularly difficult. A biome may be defined as a major regional ecological community characterised by distinctive life forms and principal plant species. More than one "habitat" type and, hence, bird community (which is habitat under the definition of the CBD) may occur within a biome; the set of sites chosen has, therefore, to reflect this. Contextual species richness is used - setting species numbers in the context of the total number of species restricted to a particular biome to ensure that a large number of sites each holding only a few of the bi-

[17] http://birdlife.net

ome-restricted species are not chosen. Some sites may, however, be chosen for one or a few species which would otherwise be under-represented, such as those confined to, for example, a restricted habitat type within the biome. Some EBAs and many biomes cross political boundaries; where so, the networks of sites has to ensure that, as far as possible, all relevant species occur in IBAs in those countries where the EBA or biome is well represented. Thus, biomes require that the networks of sites, chosen by complementarity analysis, take account of both the geographical spread of the biome and the political boundaries that cross it.

The biome-restricted assemblages, is relatively complicated to apply - in comparison to the other three criteria - and its application requires the use of ecosystem based mapping exercises.

**Category 4. Congregations**
This category applies to those species that are vulnerable as a consequence of their congregatory behaviour at regularly used sites, either at breeding colonies or during the non-breeding season, including at foraging, roosting and migratory stop-over sites. Such stop-over sites may not hold spectacular numbers at any one time yet, nevertheless, do so over a relatively short period due to the rapid turnover of birds on passage. The criteria are:
A site may qualify on one or more of the four criteria listed below:

- Site known or thought to hold, on a regular basis, more than 1% of a biogeographic population of a congregatory waterbird species. (The term waterbird is used here in the sense that the Ramsar Convention uses waterfowl and covers the list of families as more precisely defined by Rose and Scott (1994));
- Site known or thought to hold, on a regular basis, more than 1% of the global population of a congregatory seabird or terrestrial species. Includes those families of seabird not covered by Rose and Scott (1994);
- Site known or thought to hold, on a regular basis, more than 20,000 waterbirds or 10,000 pairs of seabirds of one or more species;
- Site known or thought to exceed thresholds set for migratory species at bottleneck sites.

This covers sites over which migrants congregate e.g. before gaining height in thermals. Although it is the airspace that is important, conservation of the land beneath it may be necessary to protect the site from threats such as hunting and the construction of radio masts etc. The congregatory species criterion also has regional and sub-regional applications in Europe.

The first ever inventory of IBAs was published in 1981 by BirdLife International (then ICBP) covering 694 sites in the nine member states of the European Community (Osieck & Mörzer Bruyns 1981). This was followed by the first pan-European IBA book covering 2,444 sites in 39 countries or autonomous regions in Europe (Grimmet & Jones 1989). Heath & Evans (2000) is the latest pan-European IBA inventory covering 3,619 sites in 51 countries or autonomous regions. Besides in Europe, the IBA approach is applied in other regions. These include the Middle East (Evans 1994) and Africa (Fishpool & Evans 2001). Other regional IBA inventories are currently being prepared.

The IBA selection method has primarily been designed to identify areas important for bird conservation and should not be used by itself for the holistic design of national protected areas systems. The important work carried out by millions of birdwatchers around the world, provides an invaluable basis of information and knowledge base to complement a physiognomic-ecological analysis, like the one proposed in this document. Therefore, we have integrated an indispensable check of the IBA criteria as an integral part of our method – using available data only. (See Chapter 4.3)

# 3. MINIMUM AREA REQUIREMENTS

## 3.1. SPECIES REPRESENTATION

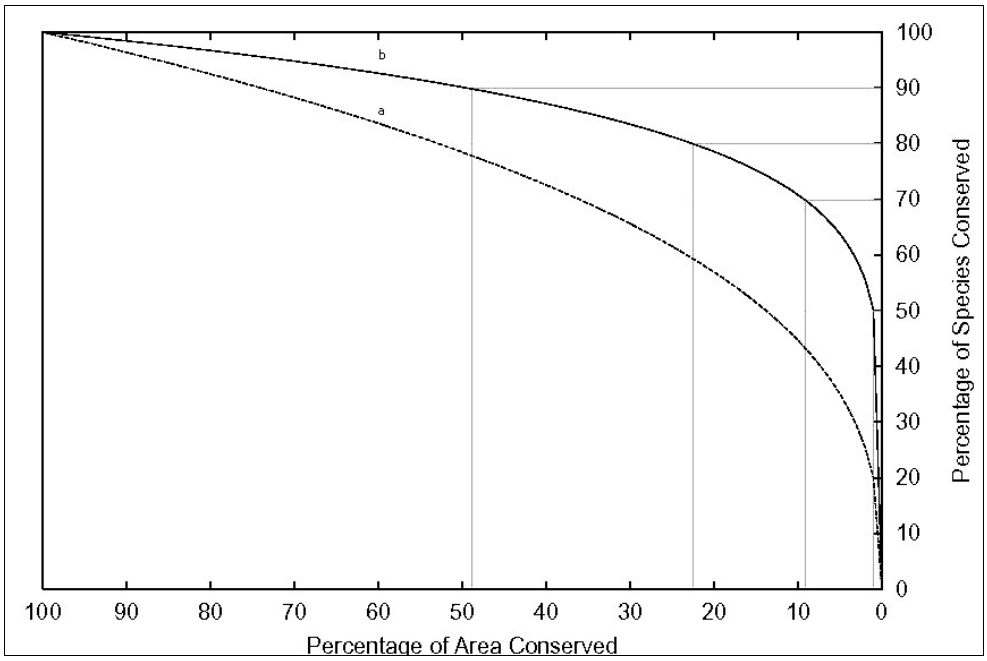



**Figure 6**: **Percentages of species conserved relative to the percentage of territory conserved**. The x-axis shows how the percentage of species numbers decreases with the percentage of remaining of any given ecosystem. Curve "a" shows the percentile species loss for $z = 0.3$ and curve "b" for $z = 0.15$.

The previous chapter dealt with methods on how and where to find different assemblages of species, but not with the question how much is needed to capture a significant representation. Within reasonably homogeneous ecosystems, species are still spread differently across an ecosystems depending on factors such as population density and micro variations in the terrain. For more than eighty years, ecologists have recognised that the size of an area of wild habitat correlates strongly with the number of plant and animal species to be found in that area. In 1921, a Swedish plant ecologist named Olof Arrhenius published a paper straightforwardly titled "Species and Area", which is considered a classical work in ecology and has been embraced by most ecologists in the world. Based on investigation of species diversity within certain delimited plots, Arrhenius (1921) concluded that the number of species increases continuously less as the area increases. This phenomenon is known as **the species/area relationship (SAR)**. This is reflected in the quantitative formula $\mathbf{S = cA^z}$, in which **S** represents the number of species and **A** the size of the area. The constant **c** is an empirically determined multiplier that varies among taxa and areas (USA Commission on Life Sciences 1995), and which may be ignored when comparing the percentages of S and A, as done in this analysis. The exponent z varies according to the topographic diversity, the isolation of the area and the mobility of the taxon. It is usually larger for islands (around 0.3) than for the mainland (commonly assumed less that 0.2). Dobson (1996) suggests 0.15. Figure 5 plots the percentages of species lost against the percentage of ecosystem lost for (a) an island situation in which z = 0.3 and (b) for a large land mass in which z = 0.15. The curve is often referred to as the "species-area curve".

Often the species-area relationship is used disregarding special differentiation in ecosystems. Welter-Schultes and Williams (1999) warn that "habitat" cannot be ignored in species-area relationship studies, and it is assumed that the SAR applies to homogenous or very gradually changing environments. The moment one passes from one ecosystem to a next, a new assembly of species gets to be included, which leads to a sudden increase in species, which is ruled by the mechanism of the SAR for the new ecosystem leads to the levelling off of the curve, until the boundary is passed into yet another ecosystem. The application of the formula to model the number of species lost or conserved requires a reasonably detailed distinction of ecosystems.

How good is the species-area power equation? Several mathematicians have attempted to theoretically explain its validity. As recently as in 2000 an attempt by Hartman (2000) to mathematically explain the validity of the curve, was rebuked by Maddux (in press 2002) and no satisfactory explanation seems to be available yet; however, none of the theoreticians seems to challenge the validity of the model itself (R.D. Maddux pers. com.). The mere convenience of its simplicity is no reason to embrace its universal validity, particularly not in the context of the present bald attempt to set minimum sizes for ecosystems. For its validity, one must rely on evidence from literature. On a small scale, the model has been commonly practiced to estimate the minimum plot sizes required for relevés or plot-sizes in different plant communities (e.g. Mueller-Dombois and Ellenberg 1974, Küchler and Zonneveld 1988). Many biologists have used the equation to predict or test species area relationships on islands, usually applying it to one selected faunal taxon (e.g. Diamond 1975, Welter-Schultes and Williams 1999). Given the numerous indications for validity and application over a period of more than 80 years, the model is considered a responsible tool for theory development to set selection criteria for protected areas systems, although opinions about the *z* values for continents varies. As always

must be the case with models, great prudence and continued alert for alternative propositions must be upheld.

Active searching of intraspecies genetic variability, which is advocated by some scientists (e.g. Moritz and Faith, 1998), is not considered feasible as it requires very intensive methods, for which there just are not enough time and finances left, while the application would also be too costly. The species-area relationship is independent of taxonomical detail and should work the same for sub-species as it does for species; by applying the principle of percentile area selection, one is bound to include the same percentages of species or subspecies. Under this assumption, this document will not deal with subspecies any further, although, specific subspecies may need special attention on a case-by-case basis.

Some ecologists have proposed alternative equations (e.g. del Valle 1996, Plotkin et al. 2000), (for a brief overview of a number of models see for instance Oksanen 2000), but no applications of those models or further references have been found in literature, and no alternative options are considered in this document.

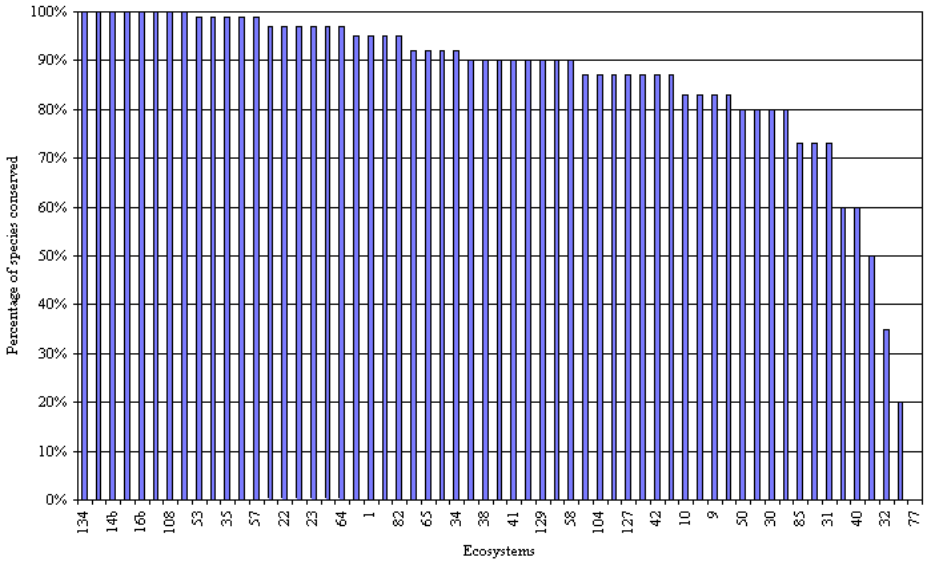



**Figure 7: Percentage of surviving species per remaining ecosystem.** For each ecosystem of protected areas model chosen in Honduras, the percentage of species conserved is plotted against the y-axis. The chosen model involves the conservation of about 17% of the country. The numbers on the x-axis refer to ecosystem codes of the Map of the Ecosystems of Central America, Vreugdenhil et al. (2002).

The goal of the Bali Declaration is to extend the global network of protected areas to cover at least 10% of each major biome by the Year 2000. Logic implies, that the species-area curve only works if applied on relatively finely established grids of ecosystems, as coarse selections would risk to exclude large numbers of species whose distribution just don't happen to coincide with the selected protected areas territoire. Maximisation of the species conservation benefits of the Bali Declaration therefore, requires more detailed bio-units than "Biomes". In the next paragraphs, it is argued that the level of detail achieved through the methodology proposed in Chapter 2 will probably provide sufficient detail for effective selection of species assemblages. If this is the case, 10% of the ecosystems of each country would protect about 70% of the species on earth, assuming a $z$ value of 0.15, while 3% would still protect about 50% of the species. 30% of the biomes protected would only raise protection to 80%, or an additional 10% of the world's species. If $z$ turns out to be higher than 0.15, the number of species conserved would obviously be lower.

To efficiently select ecosystems as proxies for species assemblages, it is necessary to arrive at much further levels of detail than previously applied in studies on continental levels. The question is, how much detail is necessary and feasible. This cannot be answered with a simple rule of thumb. Countries with considerable variation in elevation will have more ecosystems than countries with less variation. Differentiation in rainfall, absence or presence of a coast, and many more factors determine the number of ecosystems to be encountered and described in a country.

No system will do much good if it requires decades of study and hundreds of millions of dollars to apply. Therefore, a map must be appropriate in detail and production costs. The "Map of the Ecosystems of Central America" production has shown that a fairly detailed map may be produced over a territory spanning more than 1,500 km and 7 nations in less than a year of fieldwork and mapmaking. The level of detail entailed about 140 ecosystems encountered, or 30 to 60 different classes of ecosystems per country. Such level of detail requires that a team of field biologists with 15 or more years of experience, and who know the country well, determine which parameters should make up the distinguishing characteristics, thus building on decades of fieldwork of many researchers. Some greater level of detail could be achieved by applying biogeographical characteristics would they be known. Floristic detail may considerably expand the number of ecosystems, but that would require that each area represented by a polygon needs to be visited and sampled. That would be extraordinarily costly and probably extend the fieldwork period to several years. Each floristically subdivided ecosystem class would have some species

differently, but similarity among subclasses would be greater than between classes higher in the hierarchy.

Previous to the fieldwork, half a year was spent on method development; report writing took another half year of work. The costs were just under US $2 million, more than half of which for fieldwork. Considerable resources had to be spent on experimentation and method development and the coordination among so many countries. Future productions elsewhere in the world may be made at lower costs for areas of similar size and involving fewer countries. The production costs per area don't increase linearly with size. Some exercises with budgeting productions estimates for countries of different sizes suggest that indicative cost would be in the neighbourhood of the square root of the size of a country in hectares, multiplied by a factor between 50 and 100. This figure will vary depending on factors as field-access and project staffing costs.

**BOX 6: NEW GIS APPLICATION FOR ECOSYSTEM MAPPING**

Progress in GIS analysis of continuously improving remotely sensed imagery will allow for increasing detail in the future, not only in added ecological modifiers, but also in floristic characterisation. Particularly through the combined use of imagery with different characteristics, GIS-based maps may be produced that show considerable detail. D. Muchoney (pers. com. 2000) had produced an experimental vegetation cover map through supervised classification with 146 classes for Central America using AVHRR and LANDSAT 6 images, but the map was not verified on the ground. Oindo (2002) could map different degrees of faunal species richness using AVHRR and LANDSAT 6 images in Kenya and Schmid (2003) has combined LANDSAT satellite images and radar images taken from and airplane to map detailed Zürich-Montpellier classes on the island of Schiermonnikoog in the Netherlands. Such techniques will continue to reduce costs of ecosystem maps, although field analysis will continue to be required, particularly in areas where the knowledge basis of even the most common species of the identified ecosystem classes still is non-existent. Ever increasing detail, however, risks such complexity of the material to be analysed, that the selection criteria (see Chapter **4**) of ecosystems representation in protected areas system become very difficult to define and the selection process becomes hard to manage. Involvement of highly experienced field biologists for the production of ecosystem maps remains paramount.

Maps of this detail have been used in a variety of countries in Central America to analyse the effectiveness of protected areas systems, the latest in Honduras (Vreugdenhil et al. 2002). The latter case entailed the most thoroughly documented analysis, and all the areas that experienced biologists considered important and distinct could be justified with the accomplished level of detail, while some new areas were identified that were previously overlooked. Previous studies in Costa Rica and Belize, also received broad consensus by conservationists participating in the analysis, which are indications – though no proof - that the level of detail reached in Central America leads to the selection of the most important ecosystems, and it may serve as an indicative target level of detail.

## 3.2. SPECIES SURVIVAL REQUIREMENTS

### 3.2.1. From ecosystems to populations

While the organised selection of a broad representation of species should be an important goal in the composition of a protected areas system, it certainly is not the only one. After all, it would be of little avail to select a system to be very rich in species if many of those species will not be able to survive. As the selection criteria for biodiversity representation as proposed is based on many critical ecological factors, it also captures vital elements required for the survival of the species. However, one important condition for the survival of species is not incorporated in the method for selecting species and ecosystem, which is the size of the areas. The smaller an area, the more likely it becomes that populations of species will go extinct. Many conservationists are concerned about the viability of an area. MacArther, R.H and Wilson, E.O. (1967) in "The Theory of Island Biogeography" have triggered a worldwide discussion on minimum sizes of reserves.

This document departs from the assumption that all ecosystems – even the very small ones - are viable, but not each size is suitable for maintaining all the species that are associated with it. When an ecosystem decreases in size or undergoes ecological change, some species may go extinct, but a reduced or altered ecosystem continues to be viable for the remaining and probably for new species. Therefore, "viability" rather relates to the individual species belonging to an ecosystem and it varies widely per species. When this document relates to "viability" it refers to the viability of the majority of the species on an assemblage belonging to an ecosystem class, but not to the ecosystem itself. The question is how large must an ecosystem be, for a species to survive.

**BOX 7: AREA NEEDS VARY STRONGLY AMONG SPECIES**

The mountain top of Montaña Uyuca in Honduras (House, at all 2002) is just a bit under 1000 ha and it provides shelter to about a dozen of endemic plants that have been present on only that small location for who knows how many thousands of years, as they may have developed there on the spot and/or have been left behind as glacial relicts. In the Nevada's Mojave Desert, USA, 16 species of Pupfish and another 16 species in Mexico live in regions that tens of thousands of years ago contained interconnected rivers and lakes, but where (semi-)desert conditions now prevail. Being isolated from each other, "in their islands of water in an ocean of desert", these pupfish have drifted off into different species, one of them, the Devils Hole pupfish, *Cyprinodon diabolis,* has been clinging onto life with numbers varying between 200 and 700 individuals (Chen 2002). On the other hand, a number of animals need very large areas, like the big cats and the large birds of prey albeit not necessarily of only one specific class in the UNESCO system. They may happily survive in large protected areas of mixed ecosystem composition.

These examples show that every organism has different requirements regarding its population size of and its distribution across one specific or more ecosystems. The challenge is to find ways that lead to the conservation of the largest variety of species possible, of both species that live in high and in low densities while making the smallest possible territorial demands.

### 3.2.2. Minimum viable populations (MVPs)

**Development of theories on extinction due to stochastical processes at the population level**

In 1986, MacKinnon and MacKinnon (1986 a and b) stated that "the identification of the minimum size required to include viable populations of all essential species in each ecotype has been well reviewed", quoting figures varying between 500 and 10,000 individuals from authors in the first half of that decade. Since then, theories and modelling on minimum viable populations have undergone further development, reason to reassess these numbers in this context.

One of the pioneers in developing practical guidelines for conservation managers and planners is Soulé (1987), who lead and edited the composition of a conservation classical, "Viable Populations for Conservation", the textual accumulation of a previous workshop in search of the minimum size a population should have to survive without human interference, referred to as "minimum viable population" (MPV). The concept of thought regarding the limited life-times of populations have been heavily influenced by MacArthur and Wilson (1967) and Dobson (1970), who convincingly argue that insular populations of plants and animals undergo a continuous process of going extinct and being (re-)established by migrants from elsewhere and its consequences for nature reserves. Further underpinning of MVPs has taken place in various later publications of workshop presentations (Remmert 1994, Landweber and Dobson 1999) and reflects an on-going academic debate on the survival potential of species over certain periods of time. While most authors in those publications clearly approach the issue of species survival from an individual species viewpoint, their work is of vital importance, as it allows for extrapolation of their findings for collective criteria on population size for all species in a given ecosystem. In this document, the survival criteria for individual populations will be used to argue the dimensions of ecosystems required for the survival of the vast majority of the species they contain.

In his book Soulé (1987) argues that while some conservationists resent the term "minimum", it is not practical to use the term optimal, as it is prone to widely vary among the users and with prevailing viewpoints in a society. Managers and policy makers need clear, understandable and defendable relatively fixed floors below which population levels should not drop. He defines a MPV as a population that meets the minimum conditions for the long-term persistence and adaptation of a species or population in a given place. The theoretical conditions that need to be met for a population to be considered viable will be reviewed.

**Time horizon and certitude**

Conservationists – inter alia through the CBD – target to conserve biodiversity of species and ecosystems, or in other words, they try to prevent extinctions. By doing so, they have to deal with a time-horizon dilemma. Over a geological timescale, no species lives forever and ecosystems undergo continuous gradual alterations. The extinction of an established species is almost as common an event in the fossil records as the appearance of a new one. Conservationists think in a much more limited timeframe. They observe that habitat destruction and impending climatic change has started to lead to massive loss of species which occurs at such a high speed, that they fear that the rate of extinction has become much higher than may be compensated by the rate of evolution of new species. They feel the need to prevent this for at least the duration of a period that is humanly somewhat comprehensible like centuries and not in terms of geological time horizons. To do so, population dynamists work with probabilistic models (Schaffer 1987) to predict what may happen with populations undergoing change. Soulé (1987) defines the "long-term" persistence of a species as follows: A species in any given ecosystem must have the capacity to maintain itself without significant demographic or genetic manipulation for the foreseeable ecological future - usually centuries - with a certain, agreed on, degree of certitude; he suggests several centuries with a degree of certitude of 95%.

Defining the horizon of duration in terms of time (a human perspective) instead of generations (a more biological perspective), tends to favour somewhat lower requirements for large organisms, as they usually live longer, and therefore, experience a slower population

turnover, resulting in genetic processes and related risks proceeding at a slower pace (Korn 1994). This would mean that theoretically, long-living organisms - independently of external effects – should be able to survive more years at lower MVPs than smaller organisms during the same period of time. This benefit is important, as most species living at such a low densities that the viability of their population becomes impaired, have long life-spans.

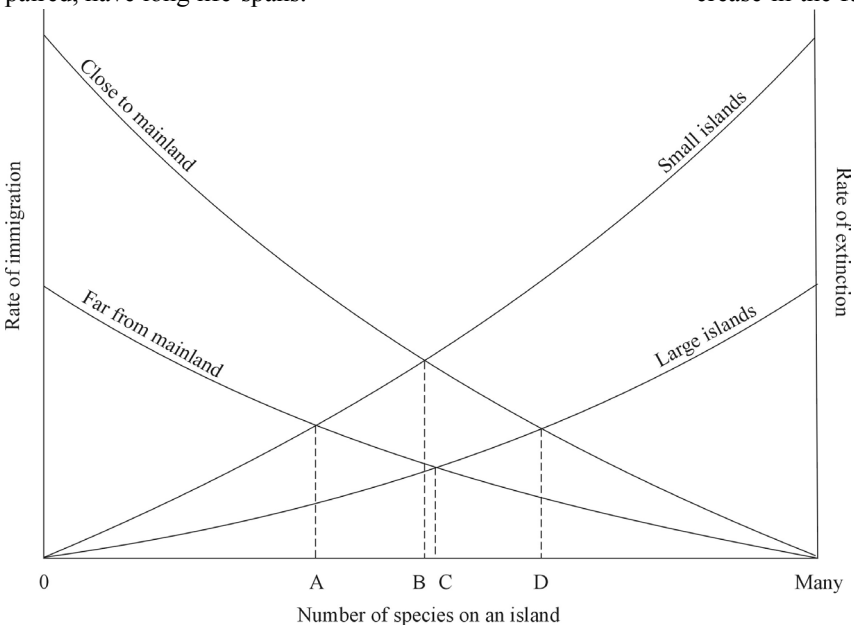



**Figure 8**: Number of species on an island after MacArthur and Wilson (1967).

Many authors claim that a few hundred years is not enough. After all, we try to conserve those species – humanly speaking – forever. When set at survival targets for a thousand years and 99 percent certitude, the models that calculate the minimum population sizes for the survival of species with large territories predict that almost the entire earth will be required for conservation purposes (e.g. see Belovsky 1987). Ciraicy-Wantrup and Phillips (1970) introduce the term "safe minimum standard of conservation", which they compare to "the objectives of an insurance policy against serious losses that resists quantitative measurement. Here the objective is not to maximise a quantitative net gain but to choose premium payments and benefits is such a way that maximum possible future losses are minimised". An insurance company cannot set its premiums to compensate for any and all possible future damages. The premiums would be so expensive that nobody would be able to afford to buy the insurance.

We must accept that we cannot look into the future forever. If mankind finds ways to somehow redistribute wealth and well-being more equitatively, peace and conservation may both benefit and grow, and conservation may remain a human concern. If this optimistic scenario cannot be achieved, mankind may altogether lose its interest in conservation, in which case, anything we do now will be in vain. Assuming the positive scenario, their possibilities for conservation may change dramatically, for the worse or for the better from a ecological point of few. For instance, worldwide, we can observe a tremendous shift from rural dwelling to city dwelling, as can already be seen in some isolated mountain regions in Oaxaca, Mexico, where the younger members of some villages have mostly migrated to the cities (Vreugdenhil 1998), leaving their native mountain regions abandoned. If the trends of the native populations of the wealthy countries are any indication, the world population may decrease in the future, and some poorly performing agro-production lands may be converted again into ecosystems suitable for large animals. In short, there are so many factors of uncertainty, that it is not realistic to set targets for eternity, while current land-conflicts are so pressing. If today, we can set conditions for the larger species to hold on to life for a few more centuries, we must count on future generations to find ways to extent that period to many millennia. Building on such uncertainties, conservationists may agree to settle for a somewhat lower certitude than 99 percent and a horizon of no more than a few centuries.

**Stochastical inbreeding depression**

Inbreeding depression is the exposure of the individuals in a population to the effects of deleterious recessive genes through mating between close relatives. Experience of animal breeders indicates that rapid inbreeding in a very small population recently founded from a large one produces substantial decreases in body size, viability, and fecundity and frequently leads to the extinction of the population (e.g. Dobson 1996, Lande et al. 1994, Ryan and Siegfried 1994). This is due to the fact that for a given locus, some alleles will confer more fitness on an individual than other ones. Within the other class of alleles are rare deleterious recessive alleles, which, when appearing as a homozygous genotype in an individual, greatly reduces the fitness. Deleterious alleles arise constantly through mutation, so they are always present in a population at low frequencies (e.g. Lynch 1995). The slower the rate of inbreeding, or, in the present context, the larger the effective population (consisting of members that effectively reproduce, often symbolised by "$N_e$") size immediately after a population crash, the greater the opportunity for selection to eliminate recessive deleterious mutations, and consequently, the less inbreeding depression is manifested. It has been suggested that inbreeding is a problem only when $N_e$ is less than 50. Ryan and Siegfried (1994) give a variety of examples of birds in which some degree of inbreeding could be expected but apparently does not occur, but they don't suggest a minimum population size.

Many more examples of survival from very low population numbers can be given, and it must be concluded that deleterious effects of inbreeding may not be the

rule, but rather the exception. The somewhat conflicting evidence on inbreeding depression indicates that this may be less of a problem than has been stated (Ryan and Siegfried 1994). Some species apparently can tolerate high levels of inbreeding.

**Stochastic reduction of genetic variation**

With countless cases of global populations having narrowly escaped extinction, it is now clear that in general, populations can survive extreme constrictions in number at least temporarily, and some over longer periods of time. Still, one wonders what happens genetically to populations that have undergone such dramatic constrictions in their population size. There is no doubt that there is considerable loss of genetic diversity when it passes through a "bottleneck", particularly when recovery is slow or bottlenecks are repeated. Such populations are likely to permanently lose considerable genetic variation, although Korn (1994) writes that going through a "bottleneck" once does not necessarily mean that a great percentage of the heterozygosity is lost, as long as the population be expanded rapidly afterwards. Skilful breeding programmes in zoos may effectively reduce some of the losses by selectively breeding back rare surviving traits in the population. In the wild - in absence of computerised mate selection - genetic variation may be corrected over time if more viable population levels can be restored and genetic variation can be regenerated by mutation. The increased population would again undergo adaptive evolution, particularly if (re-)introduced in the wild, where natural selection may further enhance variation. In fact, Korn (1994) finds that genetic variation in a founder population rapidly approaches that in a wild source population, once the effective size exceeds 25. Mathematical models of quantitative genetic variation suggest that at equilibrium, $N_e = 500$ is sufficient for mutation to counter losses resulting from genetic drift (Lande et al. 1987). However, $N_e$ normally does not reach census numbers (Korn 1994). This will usually translate into a census size of "several times" that number, when taking into account the factors that determine the participation in reproduction, like age, ratio of breeding adults, variance in family size and fluctuations in populations size (Soulé 1987); H.H.T. Prins suggests it may be as much as 5 – 10 times higher (pers. com.). Ample details on models are provided in aforementioned works and different authors write about the consequences of each variant. The details of their mechanism are less relevant for this analysis, as in this context one primarily needs to come to an understanding of the main trends that allow an approximate determination of the minimum sizes of ecosystems, and not what needs to be done to manage individual species.

**Demographic stochasticity**

Demographic stochasticity consists of individual variation in fecundity, longevity, accidents, sex ratio of the offspring, etc. In general, this rarely leads to extinction, unless the population size is very small, generally under 40, which is somewhat subjected to the population growth rate of each species (Ryan and Siegfried 1994). These numbers are well under the MVP requirements of previous factors. For very small populations (less than a few dozen), the chance that all (or most) individuals are of the same sex is "rather large" (Wissel et al. 1994), but those risks diminish rapidly with increasing numbers. A number of rodents, such as rabbits and hares, are subjected to large swings of their population sizes (Korn 1994), and such species probably have MVPs at an order of magnitude higher (Soulé 1987). But then, such species have relatively high population densities and are usually found in numbers far above MVP levels. With species numbers in the low thousands, demographic stochasticity can be ignored for long living large animals.

**Environmental stochasticity**

Ryan and Siegfried (1994) define environmental stochasticity to encompass a continuum of unfavourable conditions ranging from short-term fluctuations (particularly weather) to long-term variation (like prolonged draughts), to catastrophes (like fires, hurricanes or floods). Earlier theoreticians (Shaffer 1987) were inclined to distinguish between the effects of stochastically occurring in unfavourable environmental conditions and disasters. Disasters are different in the sense that they may wipe out an entire population all at once, and in that sense, may be regarded as independent of population size. Ryan and Siegfried argue, that catastrophes are no more than extreme environmental conditions, whose impact may largely depend on the scale of an organism and the survival strategy of each species Although Ryan and Siegfried's (1994) viewpoint is logical, the risk of full blown disasters requires special attention in risk abatement strategies, which will be dealt with in the paragraph on spreading of risks.

**Metapopulations**

Many species are patchily distributed over a grid work of their acceptable habitats (Gilpin 1987). For the more suitable parts, the densities are much higher and are likely to have larger populations, possibly higher population densities healthier individuals and greater emigration than the less suitable parts. According to the theory, sub-populations may occasionally go extinct, but as some individuals disperse from other sub-populations, formerly populated patches may be re-colonised, or genetically depleted sub-populations may be enriched and numerically strengthened. Particularly among birds with their high mobility, this rescue effect is not uncommon, even over considerable distances (Bezzel 1994).

**BOX 8: A CASE OF A DISASTER LEADING TO THE EXTINCTION OF A SPECIES**

By the 1870s the only Heath hens, *Tympanuchus cupido*, left, occupied a tiny island called Martha's Vineyard off the coast of Cape Cod in Massachusetts, USA, where in 1915 the population had risen to about 2000 individuals; In 1916 a fire burnt most of the reserve, and most hens on the nest perished. Subsequently, the population was hit by a bad winter, a disease, and in the end, there was such high predominance of males, that the species could no longer be saved (Gross 1932). If the same number of individuals would have been spread over several locations – with or without biological connectivity – the bird would have had a good chance of surviving (Ryan and Siegfried 1994)

Theoretically, this has consequences for the minimum sizes of populations, as the effects of inbreeding repression and genetic drift is more severe in smaller populations than in bigger ones. On the other hand, partial isolation may also have its advantages, particularly in the case of some types of disasters, such as the of outbreaks of highly infectious epidemic diseases, hurricanes or large fires. Gilpin (1987) reviews many consequences of the existence of meta-populations, but does not come with numerical estimates of the consequences and Soulé did not take them in consideration in his overall evaluation. Assuming survival advantages and disadvantages, no numerical consequences are generalised in this review from the phenomenon of metapopulations. For particularly vulnerable species, the meta-population specifics may need to be considered, which may lead to specific management recommendations. However, Hanski and Simberloff (1997) have downgraded the relevance of metapopulations at least in the context of this document due to the observation that most species in nature are not as structured as metapopulations in the original sense and we will not further emphasize this phenomenon.

**BOX 9: SURVIVAL BENEFITS FROM PARTIAL ISOLATION OF METAPOPULATIONS**

Partial isolation of metapopulations may reduce the extermination risk by infectious diseases. In the mid 1988s, the Harbour seal North Sea sub-population was severely effected by the outbreak of an epidemic of the phocine Distemper virus, killing 18,000 individuals in a very brief period of time. The disease only spread among the North Eastern Atlantic and did not appear to have effected the population as a whole. A similar outbreak occurred in 2002.
(http://www.scotland.gov.uk/about/CS/UNASS/00015982/home.aspx 2003).

**MVPs of plant species**

In literature, almost all considerations of MVPs are heavily focussed on animal populations (e.g. Soulé et al. 1987, Remmert et al. 1994, Dobson 1996, Landweber and Dobson 1999, Holsinger 2001). It makes sense to wonder if special considerations must be made for plants. Willmanns (1984) argues that while the "Gesetzmässigkeiten der Polulationsentwicklung" (the laws of population development) are primarily derived from animal species, that the same principles also apply to plant communities. Stacy (1997) did a study on "Mating Patterns in Low-Density Populations of Neotropical Trees" on Barro Colorado Island in Panamá on low-density tree populations. Within the study area, the density of reproductive adults (the effective population) for the three species under study, *Calophyllum longifolium, Spondias mombin,* and *Turpinia occidentalis*, ranged from one tree per 6.3 ha to one tree per 10 ha. She found that all three species were essentially 100% outcrossed, and that mating in each population involved some percentage of pollen flow over long distances. Where flowering adults were clumped, the majority of matings were among near neighbors with some small fraction of successful pollen originating from outside the clump. In contrast, where flowering adults were more evenly spaced, a large fraction of effective pollen dispersed 200 to 300 m, or farther, and well beyond the nearest reproductive neighbours. These findings of appreciable levels of moderate- to long-distance pollen movement in all three populations suggest that small Neotropical insects, which likely pollinate a large fraction of Neotropical tree species, are effective in transferring viable pollen among widely dispersed flowering conspecifics.

Based on the mating patterns observed for each species, she estimated the smallest area required for a natural breeding unit. This was defined as the minimum area in which 95% of the pollen received by a centrally-located adult originates. Using *Calophyllum longifolium* as a model of an evenly dispersed population with a low density of reproductive adults, she suggests that a natural breeding unit would extend a minimum of 60 ha. For populations characterised by clumping of reproductive trees (e.g., *Spondias mombin* and *Turpinia occidentalis*), Stacy suggests that a natural breeding unit would need to occupy at least 40 ha. This is a requirement far below the minimum ecosystem size suggested later in this chapter.

An average distance apart of 1,000 m or 1 adult per 100 ha, would require an area of 50,000 ha to maintain an effective population of 500 individuals. A limiting factor could be posed by pollinators, mostly flying insects in the humid tropics. Domestic bees, *Apis mellifera,* regularly fly 3 km for feeding, but beyond that, the chance of encountering a certain condition – in this case an individual of the same tree species, decreases rapidly, with the increasing surface of the flight radius. If tree species would live 3 km apart, a MVP would require 450,000 ha. Honey bees, however, are very powerful pollinators, compared to many other insects, and it is more likely that most tree species depend for their pollination on less powerful insects, and therefore, must live closer together. One would be inclined to think that relatively few evenly distributed tree spe-

cies live at densities of less than 1 adult per 1000 ha, but one must be alert for exceptions and individual cases must be treated with appropriate care. Until contrary indications emerge, probably no special considerations are required for tree species, but specific consultation is required on the matter among tropical taxonomists. Another factor in favour of the survival of tree species is the greater longevity of trees, which makes them less vulnerable to extinction than most animal populations during a given period.

Table 4: Rabinowitz's (1981) original classification scheme for rare species adapted from Pitman et al. (1999). Population sizes and thereby "rarity" varies resulting from the factors geographic distribution, ecosystem specificity and abundance (or rather density). The total population sizes tend to decreases from top left to bottom right. When considering global survival chances of a species, one must consider all factors that lead to population size. Locally small populations may be kept vital by periodical exchange of individuals from other populations.

| **GEOGRAPHIC DISTRIBUTION** | | **Wide** | | | | **Restricted** | |
|---|---|---|---|---|---|---|---|
| **ECOSYSTEM SPECIFICITY** | | **Wide** | | **Restricted** | | **Wide** | **Restricted** |
| **POPULATION SIZE** | **Large, somewhere abundant** | Abundant in various ecosystems in a wide geographic area. | Locally abundant but generally sparsely distributed in various ecosystems in a wide geographic area. | Abundant in one ecosystem in a wide geographic area. | Locally abundant but generally sparsely distributed in one ecosystem in a wide geographic area. | Abundant in various ecosystems in a restricted geographic area. The population size of species with a very restricted distribution may be small. | Abundant in one ecosystem in a restricted geographic area. The population size of species with a very restricted distribution may be small. |
| | **Usually low, always sparse** | Consistently sparsely distributed in various ecosystems in a wide geographic area; population size may still be considerable. | | Consistently sparsely distributed in one ecosystem in a wide geographic area. Usually rare | | Consistently sparsely distributed in various ecosystems in a restricted geographic area; rare. | Consistently sparsely distributed in one ecosystem in a restricted geographic area; rare. |

**MVP level considering all stochastical processes working at the population level**

Considering aforementioned stochastic processes that work at populations, minimum areas must be set to allow the selection of protected areas systems that may warrant the survival of the majority of the species that live in them, including the ones requiring large territories. Soulé (1987) argues that from a genetic variability point of view, the effective MVP sizes should be 500 or larger, which translates into census populations of a few thousand. Environmental stochasticity in a stable environment also requires census population sizes of "a few thousand" individuals, but obviously, no survival guidelines can be given to buffer against all disasters.

Belovsky (1987) is much less optimistic. Based on his calculations, particularly the larger mammals require reserves on the order of 10,000,000 – 100,000,000 ha, for a persistence probability of 95% during a century, assuming that each reserve is intended to support a full complement of its native mammalian fauna and does so independently of all other reserves or of surrounding, non-reserve areas. If this is true, the survival probability of particularly the larger mammals of the world is very low and mankind should consider giving up on them altogether and spend the scarce available resources on those organisms that have better survival chances. However, so far, only about 1600 species (see Table 3) have gone extinct, 85 of which are mammals, but not all were large and a portion has perished not by stochastical events but by targeted hunting and full extermination of the original habitat. On the other hand, a number of large species have been brought back from the brink of extinction and now survive successfully in much smaller reserves at population sizes of a few thousand, such as the Bison, *Bison bison*, which in Yellowstone National Park (about 850,000 ha) is kept at a total population level (N) between 800 and 2,000 (US National Parks Service, http://.nps.gov/ 2003). Fortunately, so far history does not yet seem to corroborate the high demands for population viability derived from the theoretical models presented by Belovsky (1987).

Other consideration to be made – even if the very pessimistic models are correct:

- It is not necessary that all reserves support a full complement of its native macro-fauna;
- Some space demanding mammals are becoming increasingly successful at co-existing with people and become less fully dependent on natural habitat alone;
- Aforementioned levels were set for a single remaining population on earth; most space demanding species will survive in a number of different protected areas. If population suppletion may oc-

cur – through spontaneous migration or translocation, the survival expectancy of the population of each reserve substantially increases; that situation is the point of departure for the approach in this document. Special measures are required for species on the brink of extinction;

- The recorded natural population sizes in literature of almost all species are established on hunted populations; hunted populations have sub-natural population densities and they more effectively avoid recording. This leads to lower population density estimate than would occur under the natural densities. Further, recorded densities are always lower than the real field situation. Natural populations of a number of large animals in protected areas might turn out to grow to higher densities than we now suspect if hunting can effectively be prevented.

Through monitoring and management, species with low population densities may be kept in an acceptable state of conservation in smaller protected areas than suggested by Belovsky.

Given aforementioned considerations, we follow Soulé's much more optimistic approach of a few thousand, reiterated by Ryan and Siegfried in 1994, who speak of total population (N) requirements in the low thousands. It assumes the risk of Soulé's contempt when he warns that "anyone who applies the 'few thousand' estimate as lower limit of an MVP, citing him as an authority, deserves all the contempt that will be heaped on him or her".

The strategy of this document is to establish at least one or several more or less viable populations in each country of distribution of all larger mammals, simply by establishing one or a few large areas in each national protected areas system preferably somewhere between 1 and 2 million ha. Through distribution of the species over plural national jurisdictions and geographical range, the risks of extinction becomes severely reduced, while occasional interventions before full local extinctions occur (population completion, occasional exchange of breeding stock, temporary captive breeding for truly endangered species, etc.) will further significantly enhance the vitality of populations of large animals isolated in protected areas. Such strategy enables to have the full complement of the native mammalian fauna – and with that probably most other organisms native for the reserve in question as well, while reducing the need of human intervention to rare events. In the following analysis, an effective population size $N_e$ of 500 (total population N of 2,000). Henceforward, such populations will be intended when the term MVPs and related arguments are built.

**Table 5**: Recorded extinctions[1] until 1989 (Reid and Miller 1989)

| Taxon | Mainland | Island[3] | Ocean | Total | Approximate number of species | Percentage of taxon extinct |
|---|---|---|---|---|---|---|
| Mammals | 30 | 51 | 4 | 85 | 4500 | 2 |
| Birds | 21 | 92 | 0 | 113 | 10.017 | 1.1 |
| Reptiles | 1 | 20 | 0 | 21 | 6.300 | 0.3 |
| Amphibians[2] | 2 | 0 | 0 | 2 | 4.200 | 0.05 |
| Fishes | 22 | 1 | 0 | 23 | 19.100 | 0.1 |
| Invertebrates | 49 | 48 | 1 | 98 | 1,000,000+ | 0.01 |
| Flowering plants4 | 245 | 139 | 0 | 381 | 250,000 | 0.2 |

Comments on the table:

1 Many species have gone extinct without having been recorded by scientists. Furthermore, this table gives an optimistic impression, because often species may still survive change in their habitat for a considerable period, but eventually they perish, which is referred to as "extinction dept" (Dobson 1996).

2 There has been an alarming population decrease among amphibians over the last 20 years, and many are believed on the verge of extinction.

3 The figures primarily concern the USA and Hawaii.

4 Combined species, sub-species and varieties.

When considering MVPs, one only needs to look at organisms that under natural densities live in very low densities. Those are surprisingly few, and there are a few rules of thumb to select them. There is a logical relationship between body-size and spatial requirements, although this is not straight forward as other elements play a role as well. Most notably is the equally logical relationship between trophic levels and spatial requirements. Less logical is the fact that some birds of prey require territories that are similar in size to those of large mammalian predators. May (1988) showed a reverse relationship between body-size and number of species. These facts combined are important: When considering the MVPs of organisms of areas, one needs to primarily look at the larger organisms, because the smaller organisms by and large will have viable populations if the larger ones do. This means that MVP requirements primarily need to be considered for mammals, birds, herpetofauna, fishes and trees, and of those taxa, primarily the larger species such as:

- Terrestrial carnivores with a body length over 1 m, without the tail;
- Non-migratory herbivores with body length over 2 m, without tail;
- Birds of prey;
- Trees with low distribution densities.

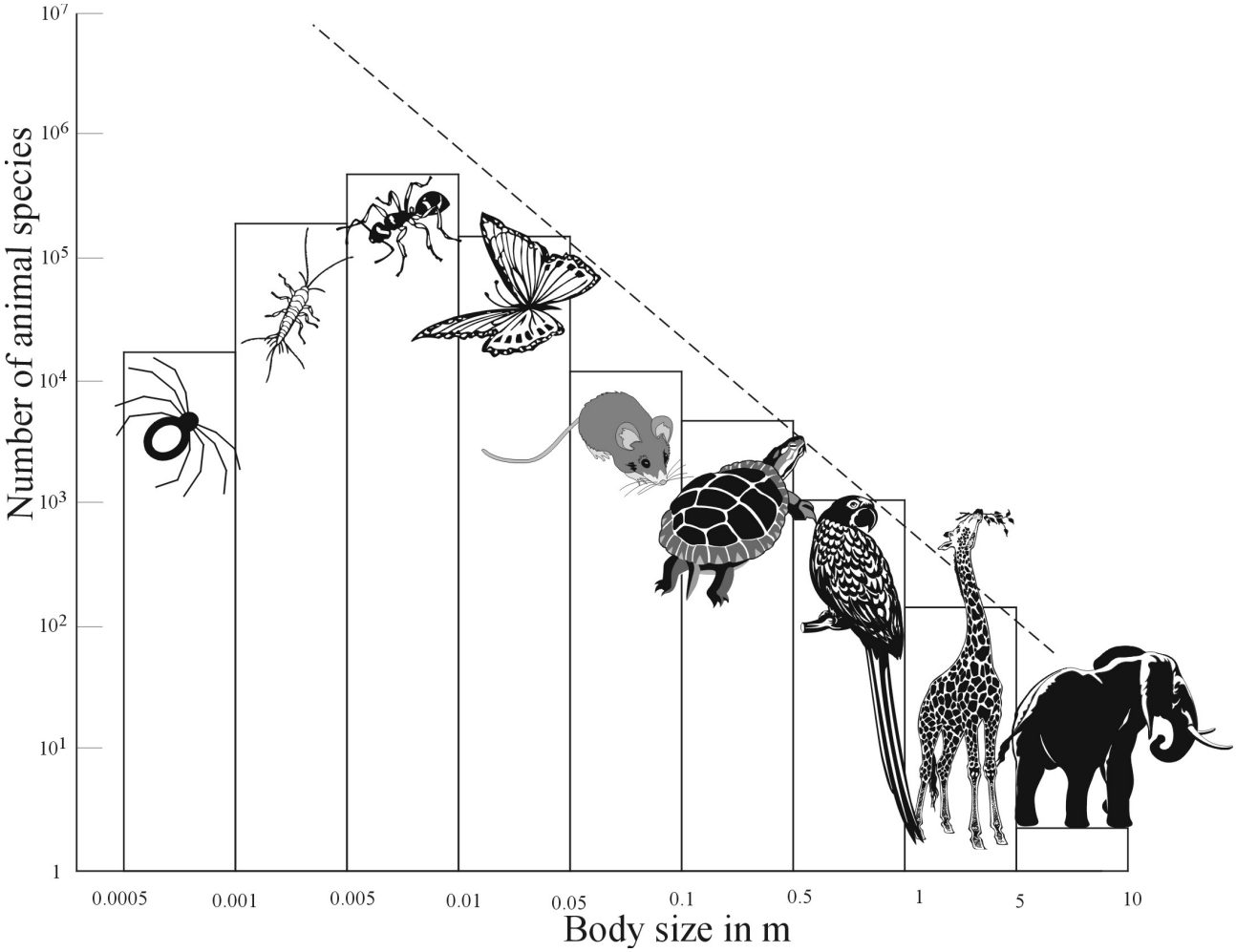



**Figure 9**: The reverse relationship between body size and number of species. Revised after May (1988).

Of most large animals, whose MVPs need specific consideration, the limiting factor seems to be primarily determined by space (Kob 1994). While each such species will probably show a general ecological preference – such as primary forest for a Harpey Eagle, *Harpia harpyja*, a savannah for Wildebeest, *Connochaetus taurinus*, and Lions, *Panthera leo*, a desert for Addax, *Addax nasomaculatus*, polar sea ice for a Polar Bear, *Ursus maritimus* – they will probably mostly be species that include a variety of ecosystems in their distribution. The best way to deal with animals requiring a very extensive territoire is in each country to select at least one very large protected area, regardless of the ecosystems it encompasses. In specific cases, translocation of large spaces-requiring-animals to such areas may need to be considered. What works in favour of the survival of populations of large animals and trees is their greater longevity. There is less generation turnover per century than for smaller organisms, thus reducing the effect of time, mentioned earlier by Soulé (1987).

Entomologists (e.g. Hoffman Black et al. 2001) have been speaking up lately, ventilating their concern that

insect species are systematically ignored, which is probably also true of fungi. Sympathetic as one can be with such concern, the methodology presented here, generally, highly favours insect survival, as those poikiloterm small creatures require relatively small territories to achieve MVPs. Only rare individual cases need specific measures, like the Monarch Butterfly, *Danaus plexippus*, whose dramatically conspicuous congregatory behaviour requires some very specific conservation measures in targeted reserves like Montes Azules, Mexico (Bohdanow 2002).

Specific attention must be paid to species with limited distribution ranges (most notably but not exclusively endemic species). Their limited natural distribution not only makes it more difficult to include their presence in one or more protected areas systems, but Rosenzweig (1999) shows that their extinction risk by nature is higher than of species with large distribution ranges. If the situation of Honduras (House et al. 2002) is any indication, it may be expected that the majority of limited distribution species be found in the remaining natural areas that coincide with ecosystems that are already required for their ecosystem requirements. By merely selecting protected areas as explained further down, the majority of the currently surviving endemic and limited distribution species will automatically be selected through ecosystems.

#### Stabilisation of populations and ecological conditions

So far we have reviewed a variety of factors that may influence the MAR of populations. What we try to establish in conservation that the populations of species in protected areas can perpetuate over longer periods. We try to lock in the original ecological conditions in smaller territories in such a way that the population densities remain more or less stable taking into account genetic and stochastic variability. Perhaps what we try to achieve in conservation can be best reflected in the word "**stabilisation**" (P. den Boer). We attempt to stabilise the ecological conditions in areas where we can keep out anthropogenic effects, or – according to need – continue their effects in a certain way in anthropogenic landscapes. The larger the area, the more stable the population of every organism that finds shelter in within it. By providing stable ecological conditions we hope that the populations of all the individual species in those areas can remain stable enough to survive the changes that people makes everywhere else to make the world suitable for themselves.

## 3.3. MINIMUM AREA REQUIREMENTS AND MINIMUM ECOSYSTEM SIZES

### 3.3.1. Regulationism versus stochastism

Before entering into the topic of minimum area requirements, a few paragraphs need to be spent on a decades old debate among ecologists.

Many ecologists see nature as a system with a high degree of mutual dependence and often refer to the "balance of nature" or its disturbance due to anthropogenic interventions. In a healthy functioning ecosystem, the population sizes of all organisms fluctuate between certain pre-determined levels and keep one another at equilibrium: the population levels are regulated. In most ecosystems predominant regulatory mechanisms are at work through which top predators keep their prey populations of herbivores as well as mesopredators under control, thus maintaining a "natural balance". Recognising that not all herbivore populations are controlled by top predators, also bottom up regulatory mechanisms have been distinguished, through which equilibriums are kept between herbivores and the plant communities they feed on. Intuitively this view is probably adhered explicitly or implicitly by the majority of biologists as well as the conservation community (including the broad public).

No, claim other population ecologists, (den Boer & Reddingius, 1996), there is no such thing as a balance of nature. Ecosystems result from the sums of infinite individual responses of organisms to stimuli from non-living and living elements in the environment. The presence or absence of populations merely depends on reproductive and dispersal success and population levels fluctuate in response to stochastic (chance) events. As the number of species in an ecosystem is higher, the number of stimuli is also higher. Mathematically it can be demonstrated that greater numbers of different interacting factors, tend to dampen fluctuations in each of the individual factors. It should be mentioned that even the most intransigent stochastists recognise that certain intrinsic regulating mechanisms occur in nature that regulate population levels, most notably territorial behaviour. Andrewatha and Birch (1954) however, suggest that territorial behaviour leads to population levels that keep populations at levels where food supply is not a limiting factor. Stochatists see territorial behaviour as a regulatory mechanism at the species level and not at the ecosystem level.

As the authors of this document have representatives of both schools of thought, the distinction needed to be made. Perhaps one of the beauties of nature is that no matter how hard we try, we just don't seem to be able to capture it's splendour in simple all encompassing rules and formulas. The debate is old and fascinating with arguments for both schools of thought and conservationists must live with differences of scientific viewpoints and still come up with answers for society. Recognising that the advancement of science benefits enormously from a divergence of viewpoints, we have tried to avoid declaring a winner, and in stead searched for common ground, which turns out to provide a very solid basis for our conservation models.

Terborgh et all (1999), argue that although the role that top predators play in terrestrial ecosystems, remains ill defined and contentious, mounting evidence from boreal, temperate, and tropical systems points consistently to a pivotal function for these animals. Species with such pivotal roles in an ecosystem are referred to as keystone species and their conservation is para-

mount in conservation strategies. Removal of carnivores from an ecosystem can unleash a chain reaction known as a trophic cascade. Under reduced or zero predation, organisms at the omnivore and consumer levels are frequently observed to increase in abundance by as much as an order of magnitude. Elevated densities of consumers then impact the vegetation via selective browsing on the most palatable species of plants. If herbivore pressure remains high, dramatic changes in vegetation composition are the likely consequence. The long-term effect of excess consumers is the substitution of unpalatable (typically, tough slow-growing) species of plants for palatable, fast-growing ones. Such herbivore-driven changes in plant community composition are severely threatening to plant diversity. Already certain species of lilies and terrestrial orchids have declined markedly throughout large parts of the eastern United States in association with elevated densities of White-tailed deer, *Odocoileus virginianus*. Some other well-documented examples include the following. Paine (1966) showed that in an intertidal ecosystem, the removal of the predatory starfish, *Pisaster ochraceous*, the diversity of the attached invertebrates subsequently declined as a superior competitor, the mussel, *Mytilus californium*, gradually occupied all available space, thereby excluding other species from the community. Another example relates to the near extintion and then gradual recovery of the Sea Otters*, Enhydra lutris,* along the Pacific rim of North America. During their absence, Sea Urchins, s*trongylocentrotus ssp.*, abalones, *Haliotis ssp.* and other benthic grazers had nearly eliminated the kelp forests of *Laminaria groenlandica* that once dominated the inshore environment. Gradual recovery of the sea otter during the middle portion of the twentieth century has led to sharp declines of benthic grazers, accompanied by dramatic recovery of kelp forests and associated fauna (Estes et al. 1978, 1989). This is a clear case of what regulationists consider a trophic cascade and what stoachists consider a far-reaching shift of the species assembly and ecosystem structure resulting from the elimination of a keystone species.

One should not assume that because top predators play major roles in regulating prey populations in many ecosystems, they play equivalent roles in all ecosystems (Terborgh et al. 1999). The prime living example is that of elephants, which are immune to predators. As adults, Rhinos and Hippos,
*Hippopotamus amphibious*, enjoy immunity to Tigers, *Panthera tigris*, and/or Lions *Panthera leo*. In the north, adult Moose, *Alces alces,* and Bison, *Bison bison,* repel Gray Wolves, *Canis Lupus,* (Smith et al. 2002); in the neotropical forest, Tapirs, *Tapirus ssp*., shrug off Jaguars, *Panthera Onca*. But size is not the only successful anti-predator strategy to have arisen through evolution. Some species are able to reduce but not eliminate predation through social mechanisms. It includes the formation of herds and flocks, sentinel behaviour, and the gearing of alarm calls (Bertram 1978; Harvey and Greenwood 1978; Terborgh 1990). Wildebeest, *Connochaetus taurinus,* aggregate in huge herds that can be within the territories of only one or two lion prides at a time. Lions are consequently unable to make much of a dent in wildebeest numbers, killing only about 8 percent of the population per. In a bad year, wildebeests die en masse from starvation and malnutrition (Sinclair and Norton-Griffiths 1979; Sinclair and Arcese 1995). Regulationists see these as cases where nature is regulated through "bottom up" regulation mechanisms, while stochastists like to see these examples as indications of how ecosystems emerge in response to ecological opportunity and not to predetermined trophic relations at fixed levels. It is important to note that for both schools these large herbivores are keystone species and that major shifts in abundance may lead to severe changes in vegetation structure and related species composition.

Stochastists predict that nature (P. den Boer, pers. com.) – in absence of strongly irregular varying dynamics (like many anthropogenic interventions) – will reach certain degree of stability in which species tend to survive over prolonged periods of time. The larger the areas, the better populations will be resistant to survive local extinctions. In stochastic processes, an increase in parameters (i.e. population levels), tends to somewhat dampen fluctuations among the individual parameter levels. As a result, greater biological diversity leads to higher all-over stability in ecosystems. Also, size is an important factor in ecosystem stability, as the chances of resettlement after local extinction is more likely in larger areas. Stability is not necessarily related to low ecosystem dynamics. Stable ecosystems may also develop under high ecological dynamics, as long as the level of dynamics remains more or less the same.

Both schools share the view that through their behaviour and consumption some species have far greater impact on an ecosystem than others and that their presence or absence may result in very differently functioning ecosystems with different physiognomic or other (e.g. plankton, benthic) structures and different species assemblies. As we have seen in previous paragraphs, all aforementioned keystone species have large to extremely large territorial needs and protected areas systems should always attempt to incorporate large continuous tracts of land. But even if the roles Lions, Tigers, Wolfs and Grisly Bears, elephants, rhinos, etc. would be utterly insignificant from an ecological point of view (which no-one claims to be the case), society at large wants those magnificent beasts somewhere in the wild. In the view of the authors, no protected areas system without the explicit incorporation of top predators may be considered comprehensive.

### 3.3.2. Minimum area requirements

Minimum area requirements (MARs) of the species are needed to calculate the minimum sizes of protected areas. The MAR can be calculated by multiplying the MVP with the reversed fraction of the density of the effective population. It usually requires some analysis to determine whether a density data found in literature concerns the **total** population or the **effective** popula-

tion – e.g. the density of breeding pairs of a bird species relates to the effective population, while a population density derived from data from a "camera trap" relates to the total population. Ranges or home-ranges of animals, often mentioned in literature, should not be used as indicators of population density. Many animals have partially overlapping ranges, while the ranges of males and females often show major differences.

If one would only select protected areas large enough to comply with the MARs of the top predators, a lot of ecosystems with their corresponding species assemblages could not be included for being far too small to host top predators. Writing off smaller ecosystems on the assumption that most of them would cascade in absence of large predators would worldwide exclude millions of species.

On the other hand, only selecting protected areas on the basis of surrogate ecological modifiers, as proposed in chapter two, bears an enormous risk that important species assemblages are missed. Particularly in the humid tropics of Malaysia, Indonesia, the Democratic Republic of the Congo and the Amazone/Orinoco basins ecological and phyto- physiognomic modifiers as not refined enough to inadequate to represent the diversity of plant communities found at both small and large spatial scales. Therefore we have sought a complementary multiple-tiered complementary approach:

- Selection of one or a few large areas to accommodate the MARs for the most space demanding – but ecologically – **broadspectrum** – species and maximum ecological stability;
- Selection of all the ecosystems to accommodate the vast majority of the less space demanding – but ecologically narrower spectrum – species for maximum species representation;
- Complement the search with the criteria of Birdlife International for the best-known taxon in the world, the birds.

A fundamental question is, how much area is needed of each ecosystem to allow the required life-supporting ecological processes to perpetuate for their species. To that end, some concept of minimum area requirements had to be established for ecosystems rather than for populations. To that end, the current theories of population dynamics alone don't provide workable criteria, reason to develop some new concepts.

When species are eliminated, certain shifts of population densities will always take place; other species may disappear in their wake and others may move in, often not desirable ones. The degree of change will be different in each case, depending on a large variety of factors. One of those factors is that more often than not, small protected areas are usually islands in a "sea" of production land, and according to the island theory, they are likely to lose species. It is safe to assume that almost all small protected areas end up in a state of "extinction dept[18]" (Dobson, 1996). Some extinctions can be prevented through management measures, but this is often costly and in many developing countries, the required finances for management are usually absent and know how is deficient everywhere. How severe ecosystem changes in small protected areas will be, will vary for each isolated ecosystem, but one thing is certain, without complementary small protected areas to protect the ecosystems absent in the large protected areas, all species depending on those absent ecological conditions would be lost. We believe that it is better to conserve the absent or underrepresented ecosystems in small protected areas than not at all. In our approach, we explicitly include them in the protected areas systems, even if though a part of their species will not be able to survive.

### 3.3.3. Terrestrial ecosystems

That brings us to an interesting challenge. Some ecosystems are usually found in rather small spaces, such as montane ecosystems on some mountain tops or some isolated small waterbodies. Apparently, some ecosystems most of the time occur in small areas, while other ones – such as non-inundated prairies, savannahs and lowland tropical rain forests - occupy enormous continuous spaces. If one were to define a minimum size to fit all ecosystems, it would have to be rather large; much larger than the sizes in which those smaller ecosystems are often found. An attempt to deal with ecosystem requirements of different levels of classification has been made by TNC (Secaira et al. 2001), when observing that for the higher (coarser) levels of the hierarchy ecosystems require different "typical sizes". They argue that species adapted to living in typically small ecosystems need less space to "be representative and viable" than species in large composed ecosystems.

In elaboration of the concept, Secaira et al. (2001) are not very practical. They argue that if the typical area of an ecosystem is between 10 and 2,000 ha, the minimum size should still be 2,000 ha for areas from 2,000 ha to 200,000 ha they suggests that the minimum size should be 5,000 and a next level up (the "ecoregion") one should take 10,000 ha. These sizes are not corroborated with any criteria, and this document makes an attempt to further the concept.

The minimum size of an ecosystem should be large enough for the survival of the majority of the species that belong to that ecosystem without human intervention (management). That means that those species must have viable populations, which requires that all natural ecological processes must proceed naturally. In naturally small ecosystems, the species that depend on such ecosystems must have low MARs or otherwise they could not persist under those space-restricted conditions, whereas a number of species primarily depending on large ecosystems may have much greater

[18] A state in which species have not yet gone extinct, but whose survival has become very unlikely due to changed ecological conditions

MARs. No doubt, the distinction is artificial, and each ecosystem has its own unique set of species, but for a process of rational selection of biodiversity to a space-restricted protected areas system, one must use some size differentiation among the different ecosystems of a country. Recognising this objection, different sizes are elaborated on the basis of considerations and criteria at the population level of individual species.

Such criteria are likely to vary regionally as may appear from the following example. Paramos in Central America are typically small ecosystems, but – depending on the level of classification detail – they are probably typically medium size ecosystems in the vastness of the Andes region. The categorisation of the typical sizes will need to be done on the bases of expert assessment, considering currently existing sizes, probable historical occurrence and ecological characteristics of each ecosystem. The resulting typical minimum sizes should provide durable shelter to the majority of the populations of organisms primarily depending on that ecosystem, and not all species. Minimum populations of ecologically broad-spectrum species requiring large territories do not need to be able to survive in the ecosystems identified at the level of finesse that has been applied in the Map of the Ecosystems of Central America for two reasons:

- As much as possible, different ecosystems should be selected to occur in continuous clusters, thus providing more space for ecologically less demanding species;
- At least one or several areas will be selected on the criterion of maximum available size, rather than ecological composition, which should at least in part deal with a good number of ample space demanding organisms.

As there is a principle difference in connectivity between terrestrial ecosystems and aquatic systems, the typical minimum sizes are dealt with separately. Most aquatic systems are so well connected, that even if the different recognised ecosystems are separated over significant distances, the populations are still connected by water, although some caution is warranted: Limnic systems have almost un-restricted connectivity from up-stream to down-stream, but visa versa, only species with active swimming ability or airborne or terrestrial mobility are highly connected.

**Typically large terrestrial ecosystems**

This document uses the case of Central America (Vreugdenhil 2002) as a very suitable example as it spans about 1,500 km of length, has a high level of detail for an ecosystem map based on satellite imagery and is of a very recent production. There are 11 ecosystems of more than 200,000 ha left, of which the "Tropical evergreen broad-leaved lowland forest, well-drained" is the largest. The tropical semi-deciduous broad-leaved well-drained lowland forest is slightly under that size, but this ecosystem must have been well spread along the Pacific lowlands. The typically large ecosystems are shown in Table 6.

When analysing these very large ecosystems in Central America, all of them also occur in smaller natural patches within much larger clusters of natural ecosystems of different composition. A few of them – the ones marked TLE in Table 1, occur or probably have occurred as very large ecosystems almost anywhere before conversion of land for production purposes. The other ones exist in smaller sizes anywhere between what have been considered typically large or typically small ecosystems. Those are considered typically medium size ecosystems that shall be dealt with in later paragraphs.

What would be a responsible minimum area requirement of those ecosystems? The largest ecosystem, IA1a(1)(a), still occurs without major interruptions – except for the Panama Canal - from Colombia to the border of Costa Rica, and in the past it may have extended into Honduras and maybe, even Southern Guatemala. A case exists of well-documented isolation of this ecosystem for a period of about eighty years: Barro Colorado in Panamá, a 1,564 ha patch of forest, isolated from its surroundings by the rising water of the Panamá Canal since 1914. The area has been intensively studied since it was declared a biological reserve in 1923 (http://stri.org 2002). Scientists have documented that 18 species of birds out of a total of 318 (http://www.ctfs.si.edu/index.htm), or 5%, have been lost since its detailed observation started in the early nineteen twenties. This suggests a considerable resilience of many species to size reduction through physical isolation.

As argued previously, the categorisation of "typical" sizes of ecosystem is artificial, as in reality there is a continuum in which each ecosystem is slightly different from every other one. Also, the typical size depends on the detail of classification. A solid theoretical foundation would depart from argumentation at the population level but no consistent trains of thought were found defendable. Still, the methodology of selection of biodiversity to protected areas systems requires some degree of spatial quantification of the ecosystems and during the application of the rationalisation of the protected areas system of Honduras it was decided to empirically depart from different sizes and hold their application against some of the known densities of large space demanding species. The following sizes have been used but should be subject to future analysis and modification.

An area of 10,000 ha – 6 times the size of Barro Colorado – of stand-alone typically very large-scale ecosystem would provide viability to the majority of its animal populations with densities of 1 individual per 5 ha or denser, which is enough for most herbivores except the very large ones, as well as the medium-size predatory mammals.

**Table 6: Very large ecosystems in Central America with suggested typical dimension categories**

| Ecosystem | Code[19] | TLE[20] | TME |
|---|---|---|---|
| Tropical evergreen broad-leaved lowland forest, well-drained | IA1a(1)(a) | ● | |
| Tropical evergreen broad-leaved lowland forest, moderately drained | IA1a(1)(b) | ● | |
| Tropical evergreen broad-leaved submontane forest | IA1b(1) | | ● |
| Tropical evergreen seasonal broad-leaved lowland forest, well-drained, Mosquitia variant | IA2a(1)(a)-M | ● | |
| Tropical evergreen seasonal broad-leaved lowland forest, well-drained, on rolling karstic hills | IA2a(1)(a)K -r | | ● |
| Tropical evergreen seasonal broad-leaved lowland forest, moderately drained | IA2a(1)(b) | ● | |
| Tropical evergreen seasonal broad-leaved lowland forest on calcareous soils | IA2a(1)(b)K | | ● |
| Tropical evergreen seasonal broad-leaved lowland forest on calcareous soils | IA2a(1)(b)K | | ● |
| Tropical evergreen seasonal needle-leaved submontane forest | IA2b(2) | | ● |
| Tropical semi-deciduous broad-leaved well-drained lowland forest[21] | IA3a(1)(a) | ● | |
| Short-grass waterlogged savannah with needle-leaved trees, Mosquitia variant | VA2a(1)(2)(g)-M | | ● |
| Tectonic lake[22] | SA1b(2) | | ● |

[19] UNESCO codes as used on the Map of the Ecosystem of Central America.
[20] TLE: Typical large terrestrial ecosystem; TME: Typically medium size terrestrial ecosystem.
[21] With 164,000 ha this currently no longer is a TLE, but this ecosystem must have been much larger in the past and is considered as such.
[22] The criteria have not been applied to aquatic ecosystems.

This should be enough for the survival of most species[23]. In the Americas, this does not provide MARs for the following species[24] with large area requirements: Puma, *Felis concolor*, Jaguar, *Pantera* onca, Wolf, *Canis lupus,* Brown Bear, *Ursus americanus*, Grizzly Bear, *Ursus arctos*, Spectacled Bear, *Tremarctos ornatus*, Tapir, *Tapirus ssp*., Bison, *Bison bison*, (Nowak 1999), Harpey Eagle, *Harpia harpya*, (Grzimek et al. 1973) and King Vulture, *Sarcoramphus papa*. It would, however, under very favourable conditions provide MARs for many larger mammals, including all primates, all Deer species, both Peccaries, *Tayassu ssp.*, and the Giant Ant Eater, *Myrmecophaga tridactyla* (See also Box 11). Under less favourable conditions, fewer species may maintain their population at a viable level. It should be emphasised, however, that if this targeted ecosystem size were designed to provide shelter for the last remaining populations of the larger mammals, it would be grossly undersized and inadequate. That, however, is **not** the purpose. It is meant as a building block for the selection of ecosystems to protected area systems, which only in their combined composition maximise both species diversity and survival durability of all species, including the ones that require large territories.

**Embedded ecosystems**

Species are usually associated with one specific ecosystem, while in reality, many species live in habitats consisting of mosaics of one or more small-sized ecosystems embedded in one or more different ecosystems. Most mapped ecosystems are artificially cut up, while in reality, many species are distributed along gliding scales of density along gradual changes, which in turn, lead to development of meta-populations. As a result, individual species distributions unavoidably deviate from the mapped ecosystems and even many ecologically selective species belonging to small ecosystems, also occur in parts of neighbouring ecosystems, albeit in different densities. It is very common that mapped small ecosystems embedded in larger ecosystems are complemented by finer-grained mosaics of similar conditions that could not be mapped, and which allow species to live in mosaics of much larger territories than an ecosystems map seems to suggest. Such small patches of ecosystems embedded in intact large ecosystems provide viable conditions for the populations that have developed under those circumstances.

**Typically small terrestrial ecosystems**

In principle, these ecosystems represent relatively rare conditions, such as high elevation levels, fresh water systems as well as ecological transitions or ecotones. With less common ecological conditions, one would expect fewer species to have been developed to live under those conditions, but typically isolated ecosystems like high elevation environments may be prone to high endemism[25], and one would expect relatively low species diversity but high occurrence of relative rarity. It would make sense that the species dependant on those conditions would occur in relatively high densities, that would allow for their continuation required for their populations to be viable, probably showing densities much higher than one adult per ha. Obviously, species requiring large territories cannot fully depend on typically small ecosystems. The ones that occur in typically small ecosystems are species that require large habitats that span different ecosystems including small ones; some are highly mobile species – like birds of prey – that may cover very large areas for foraging and/or search of a mate. Some mobile species that live in low densities may require very small ecosystems for a specific function in their lifecycle, like reproduction or for bridging an unfavourable season in their habitat– while foraging in a much larger range.

For terrestrial ecosystems (not belonging to small islands and not embedded in larger ecosystems) of a characteristic size of up to 5,000 ha, it would be wise to strive for a minimum area of 1,000 ha if such ecosystems are isolated in small protected areas or located along the edges of a larger protected area. This would allow for MVPs of species requiring 1 individual per 0.5 ha. Embedded, these ecosystems would not require a minimum size, as they occur in the size of their original development, which per definition should be considered viable. Examples are high elevation tropical peat bogs and dwarf shrub communities. When occurring at the outer limit of a natural habitat, an extra zone of a minimum of 200 m (see edge effects) should be allowed for an ecosystem to meet the 1,000 ha criterion.

**Populations of species on small islands**

Much has been written on populations on islands since Diamond (1975). Given the special ecological position of islands, it would make sense to consider their ecosystems to be different from mainland ecosystems, even if their physiognomic and ecological conditions are identical to ecosystems encountered on the mainland. This means that frequently, ecosystems of small islands will fall in the category of typically small ecosystems. Particular attention needs to be paid to individual populations of endemic species or subspecies and it must be made sure that protected habitats exist where a specific MVP can survive. Also, be aware that usually, altitudinal zonation on islands is mostly compressed as compared to high continental mountains (van Steenis 1961, Grubb 1971), so that

[23] These criteria need reconsideration for areas with migrating ungulates, the low-diversity macro-ecosystems of the Northern Arctic and deserts.

[24] This list is not exhaustive. More species are listed later in this chapter.

[25] This is not, however, a trend common to all typically small ecosystems; e.g. limnic ecosystems – many of which may be considered typically small - show a contrary trend which may be explained from the high connected ecologically of aquatic systems.

elevation zones cannot be compared directly with the zones at the same elevation on the mainland.

**Typically medium size terrestrial ecosystems**

Between typically large and small terrestrial ecosystems are the typically medium size ecosystems, ranging from 5,000 to 200,000 ha. The characterisation of this ecosystem size category is obviously between the other two. Given the clearly more restricted size of this category, migration is likely to be more restrictive and endemism is more likely to have developed. By taking the lower level of the category as the MAR, this should allow for a reasonable safety level for MVPs of any organism living at densities of one reproducing pair per 2.5 ha. Under stand-alone conditions, this would probably still allow for prolonged survival of most of the medium sized ungulates as they occur in the Americas south of the United States. Possibly, under very favourable conditions, one of the heaviest of the American monkeys, the Howler monkey (*Alouatta palliata*), may occasionally have MVPs under those conditions, assuming an average total population density (N) of about 1-3 individuals per ha (e.g. Higgins et al. 2000), as well as all other – smaller – New World monkeys, but the larger Spider monkeys (*Ateles spp*.) may not. Giant anteaters, *Myrmecophaga tridactyla*, sometimes believed to live in large territories, have densities recorded of 1.3 per ha, which would allow for MVPs, which would also be the case for sloths, Megalonychidae, with densities recorded at 6-7 per ha, (Nowak 1995). The observation is reiterated that the purpose of these minimum sizes is to capture species diversity while population survival of larger animals is strived for through combined assemblages of ecosystems in larger protected areas.

#### *3.3.3.1. Aquatic ecosystems*

Some of the most threatened ecosystems on earth include freshwater ecosystems, coastal ecosystems, wetlands and coral reefs (Glowka et al. 1994), and special attention must be given to the conservation of such ecosystems. This is not easy, as it is rarely possible to consider complete water systems. One must consider both the quantitative and qualitative aspects of the water system (ranging from watersheds, estuaries, coastal waters to minuscule isolated pools) as a whole, in which many recognised ecosystems are ecologically connected inter-dependent subsystems.

**Limnic ecosystems**

In limnic watersystems, ecosystems may be very small and specific species may be associated with them for at least part of their life-cycle. These ecosystems are often linear in shape and too small to be recognised on and delineated from satellite images. Even though species may have specific ecological preferences, many populations of aquatic species cover much larger areas than the ecosystems where the majority of them are found during a specific time of their lifecycle. In other words, most small aquatic ecosystems will be embedded in larger watersystems and their organisms, usually will have viable populations, if they live in a healthy integral watersystem. Protected areas rarely encompass complete watersystems, and their viability must be assessed on a case-by-case basis, taking into consideration the human activities that take place in a watersystem. Furthermore, dimensions of water bodies may vary greatly over time, depending on seasonal water tables and the meandering of rivers. This must be given special attention when designing protected areas. Usually integral water management of the entire watershed of such systems is required to warrant the integrity of flora and fauna of gazetted wetlands.

Transitional water-land ecotones are essential, but not all shore territory needs to be included in a protected areas system and special connectivity between such zones usually is not essential[26], as non-territorially connected "stepping stones" are usually sufficient to connect populations over large distances. Furthermore, unlike terrestrial ecosystems, open water ecosystems are heavily dominated by fauna. With most limnic fauna being poikilothermic, species apparently can live at much larger densities then endoterm fauna species (Dobson 1996) in terrestrial ecosystems. No data have been found on fish species that could not live in an isolated water of less than 1,000 ha with a MVP of a few thousand, but this requires further review. Thirdly, most terrestrial ecosystems are traversed by rivers, and they practically always include aquatic ecosystems. These aquatic elements surrounded by predominantly terrestrial ecosystems are usually part of watersystems that reach far beyond the protected area, and consequently, the viability of the aquatic species in such areas are subject to the integrity of those entire watersystems, or at least their upstream part. Given these considerations, no minimum area is considered necessary. Neither is the specific selection of river parts necessary in a protected areas system, unless they are conspicuously scarce or absent. Special consideration should be made for the few species that do require larger ranges, like the fresh water dolphins and manatees. Those species fall in the same concern as migratory fish (e.g. catfishes in the tropics and salmonoids in temperate climates): species that require species oriented attention, wielding protection or use-regulation and measures, such as fish-ladders, to warrant connectivity.

**Marine and estuarine systems**

Marine ecosystems are part of enormous connected spaces with most species either being extraordinarily mobile, spanning very large areas or even entire oceans or enjoying very effective dispersal resulting from oceanic currents. When one speaks about marine protected areas, in practical terms, one must speak about protected areas in the exclusive economic zones of nations (UN, no date) of 200 nautical miles, as beyond that zone, individual nations lack sufficient jurisdiction to regulate ecosystem protection. Usually it is not (politically) possible to apply the traditional protected area concept to marine areas. The IUCN Centre for Medi-

[26] On the other hand, it is sometimes easier to protect woody vegetation along rivers, which may than serve the connectivity of terrestrial species.

terranean Cooperation (2003) convened a workshop in Malaga, Spain to address this issue and concluded that a worldwide network of Marine Protected Areas is required in the "High Seas", as they include rare and unique ecosystems and species found nowhere else on the planet. Those areas need to be created outside the territorial sea and Exclusive Economic Zones and above the "outer continental shelf" of coastal nations.

Within the coastal seas, restrictions to access are often far less accepted then over land. Protected areas usually involve a set of negotiated specific restrictions, to regulate resource use, rather than the access, that is commonly known for parts of protected areas. In a sense, providing shelter to organisms in marine protected areas is similar to providing shelter to migratory terrestrial fauna (e.g. migrating ungulates, shore birds, passerines). One provides oases of protection to populations that are exploited elsewhere as opposed to resident populations in self-sustained protected areas.

Estuarine areas vary greatly in size, but most would be in the range of typically medium size ecosystems. Intertidal zones and brackish inland lakes often are medium size (Including mangroves and extended mud-flat areas "Wadden"). Usually, brackish inland lakes are at least periodically connected and aquatic organisms move back and forth between brackish and freshwater conditions, brackish conditions and the sea, or all three. Dimensions of the water bodies may vary greatly in time, either through tidal movements, seasonal influx of water and morphological variation of the area. This must be taken into consideration when delineating protected areas.

### 3.3.4. Large protected areas

The size of a country allowing, one should strive for at least one area or complex of contiguous areas of a minimum of 1 percent of the national territory, preferably larger, in which large birds of prey and mammalian predators may keep up a healthy population and where large herbivores may roam. Real life availability and minimum needs vary from country to country, depending on the requirements of the animals with the largest territorial requirements.

In general, animals with large territories are more ecologically tolerant and may span plural habitats and be resilient to human presence if not hunted. Many may leave natural habitats and roam through rural areas. If left alone, individuals may connect with populations of their kind in other protected areas, thus breaking their genetic isolation. In most rural societies, farmers are inclined to hunt down every predator that roams the region, and most farmers don't enjoy the visit of a herd of elephants either. Their need for hunting might be diverted if farmers are compensated for the occasional kill of a domestic animal or crop loss (Vreugdenhil 1992), e.g. in the Netherlands farmers are compensated for crop damaged caused by wintering geese (van Dijk, pers. com.). This will be dealt with in Chapter 4.5.

**BOX 10: TERRITORIAL NEEDS OF THE WORLD'S LOWEST DENSITY TERRESTRIAL ANIMALS**

This box cites the densities from literature of the world's most territory demanding species, large endothermic predators[27]. Population densities of many animals are poorly known and vary greatly, depending on habitat – which for several of the cited species may vary from closed forest to semi-desert conditions. The numbers are not the result of extensive literature revision and only serve as an indication for the order of magnitude required to maintain complete ecosystems with all trophic levels in different parts of the world, but it is expected that only a few birds of prey need to be added to the twenty-some very low density species cited in this box.

Particularly in areas with low organic production levels, like semi-deserts and tundras, indicated densities may be considerably lower than the figures cited and sometimes very large areas are needed. Such areas are usually not determined by criteria of composition of ecosystems but rather by mere availability. In the future more and better data as they become available may be published on: http://www.birdlist.org/nature_management/national_parks/national_parks_systems_development.htm. It is recommanded that all species in need of more that 100,000 ha be monitored in protected areas to assess the compliance with a minimum effective population of 500 individuals.

Jaguars, *Panthera onca*, whose densities have only recently become slightly better observed with camera traps (WCS 2002) are found to have densities of 1 territorial adult per 2500 ha (effective population) in Brasil[28] (Nowak 1999), while in Cockscomb[29], Belize a density of 1 per 200 ha (total population) was found (Garman 1997), with probably an under-censused population in the case of Brasil. Still, assuming the low density to be the rule, an effective population should be able to survive in 1,500,000 ha. If the density in Belize is any indication, considerable smaller areas might suffice if hunting can be as effectively controlled as in Belize. For Pumas *Felis concolor*, densities in the USA are found to vary from 1 per 2,000 – 20,000 ha, while a case has been reported of 1 per 1,400 in Patagonia, Argentina. Total population density of lions, *Panthera leo,* for the Serengeti

[27] Poikilothermic predators usually tolerate rather high population densities, e.g. crocodiles.

[28] Measurement through teletracking, which has been found to underestimate population density (WCS, 2002).

[29] Cockscomb is currently studied with camera traps (WCS, 2002)

ecosystem have been reported 1 per 1.200 ha and other areas up to 1 per 5,000 ha, which in the Serengeti would require about 2,500,000 ha and 10,000,000 ha under less favourable conditions. With tigers, *Panthera tigris,* no longer finding natural conditions in most of its remaining distribution (except Russia, de K. Korte, pers. com.) it is hard to approximate natural population densities, although Nowak reports a density of 1 per 1,900-15,100 ha for males and 1,000-5,100 ha for females from a study in Nepal, from which an effective population density may be deducted. Population densities of Leopards have been recorded from 1 per 100 ha under exceptionally favourable conditions to 1 per 3000 ha. Cheetahs, *Acinonyx jubatus*, lives at densities between 1 per 2,000 to 10,000 ha, but may decrease to 1 per 25,000 in semi-desert conditions. Other cats living at densities whose MVPs require special attention are: Snow Leopard (*Panthera uncia)*, Clouded Leopard (*Neofelis nubulosa)*, Asian Golden Cat, *Felis Temminck*, Caracal, *Felis caracal*, Eurasian Lynx, *Felis Lynx*, and Canada Lynx, *Felis Canadensis.*

Bears usually live in considerably higher densities, for which Nowak (1999) reports total population densities: e.g. American Black Bear, *Ursus americanus*, 1 per 70-260 ha; Brown or Grizzly Bear, *Ursus arctos*, 1 per 150 – 6,000 ha, (which is obviously heavily influenced by hunting pressure and habitat conditions), Asian Black Bear, *Ursus thibetanus*, 1 per 10 – 130 ha; Sloth Bear, *Ursus ursinus,* 1 per 10 ha and appear to be able to maintain an MVP in areas somewhere between 100,000 and 500,000 ha. The Spectacled Bear is not listed, but given its size, it is expected to have ranges comparable to those of the Asian and American Black Bear.

Canines are often heavily persecuted and low population densities listed are no doubt the result of a combined effect of less favourable habitat conditions and hunting: Grey Wolf, *Canis lupus,* 1 per 2,000-27,300 ha; African Hunting Dog, *Lycaon pictus,* 1 per 3,000-50,000 ha (which is obviously heavily influenced by hunting pressure and habitat conditions), Maned Wolf ,*Chrysocyon brachyurus,* 1 territorial adult per 1,300 ha (effective population). The Red Wolf, *Canis rufus,* The most needy among the canines appear to need areas in the range of 1,000,000 to 2,000,000 ha, provided that hunting be effectively stopped in those areas. Of the Hyena's, only the Brown Hyena, *Hyaena brunnea*, which primarily lives in arid regions, appears to live in very low densities with densities that may vary from 1 per 500 to 1 per 13,000 ha.

Large herbivores, live in much higher population densities than mammalian predators. Nowak (1999) reports that a relatively undisturbed population of 500 elephants lives in about 350,000 ha in Amboseli National Park in Kenya, suggesting a total population density of 1 per 700 ha, which would require a minimum area of 1,400,000 ha for a viable population. Frequently Elephant densities are much higher (S. van Wieren, pers. com.). For most ungulates, however, areas of 100,000 ha suffice to maintain MVPs. Tapirs, *Tapirus,* who mainly live secluded solitary lives, may reach densities of 8 per 1,000 ha in very lush vegetation, which would require 250,000 ha for their MVPs.

Some terrestrial mammals are nomadic, e.g. Wildebeests, *Connochaetus taurinus*, Reindeer, *Rangifer tarundus* and Saiga antilopes, *Saiga tatarica*, shifting between seasonal ranges over distances that often cannot be protected in a single protected area. For migrant mammals, protected areas serve as seasonal oases of safety, but additional measures are needed to bridge their survival between reserves.

### 3.4. CONGREGARIOUS AND MIGRATORY ANIMALS

Species that congregate for specific functions, like roosting, (a) reproduction, e.g. pan-tropical marine birds (K. de Korte, pers. com.), turtles; (b) wintering - many birds (see Delany and Scott 2002) and some species of butterflies (Srygley et al. 1996, see also http://users.ox.ac.uk/~zool0206/index.html); or (c) mating (e.g. sea-lions, many ungulates), don't fit under the considerations of species density. Flying species usually are not demanding the integrity of their entire routes or international flyways but rather the availability of specific stepping stones, where some but not all congregate. Many sites of congregation will coincide with the mapped ecosystems, but their presence is additional ecosystem information, and as such, important congregation sites need to be mapped for each country if the site represents more than 1 percent of the world population of one or more species, thus applying a Ramsar criterion (Ramsar Convention Bureau 1997) to the congregation sites of all fauna populations. For Wetlands International (http://wetlands.org), Delaney and Scott (2002) list 2,271 biogeographical populations with their sizes of all 868 species, recognised as waterbirds occurring throughout the world; this is an important reference for qualifying species. Specific attention must be paid to remote islands with colonies of pan-tropical marine birds and mammals.

For such cases, specific measures are required. Periodically flooded and intertidal ecosystems are usually small to medium size, but when considering size, specific care must always be given to congregational animals, and it must be made sure that sites of congregation are large enough for the animals to enjoy their period of congregation without disturbance. This may sometimes require a considerable area to buffer against disturbance, although such bufferzone may consist of land under production. As many sites of congregation are only seasonal, the degree of protection may be defined for the season of congregation.

Flightless migratory terrestrial and limnic fauna may have specific conservation needs for their migration routes involving the conservation of potentially the entire migratory route or at least protective measures warranting undisturbed passage during migration, which for aquatic fauna may involve technical measures like fish ladders and environmental flow agreements with reservoir management institutions.

Migratory (wintering) species that don't congregate can only be treated like resident species, and the conservation of sufficient required habitat in principle should be achieved through the same mechanism as for resident species, which is through ecosystem selection (G. Boere, pers.com).

## 3.5. SOME ADDITIONAL CONSIDERATIONS

### Plural repetition of MVPs

In all calculations, the populations have been treated as though they would be the last remaining population on earth. Fortunately, most are not, and species whose populations are near MVP levels in a certain protected area are likely to have populations protected several times usually within in the protected areas systems of each countries of their distribution. As a result, their worldwide survival would be much more optimistic than the MVP calculations appear to suggest in this approach. This will allow management aid to many isolated populations in areas where populations risk falling under their MVP to counter genetic drift, population collapse or disasters. For each country, the species need to be identified that risk occurring near or under their MVP levels. That would leave most other species resident to the protected area system of that country secure.

### Area-size-related species interaction

The disappearance of certain species from an ecosystem may have an impact on the population development of other species. On Barro Colorado Island in Panamá, the mid-sized predators, particularly the Coati Mundi (*Nasua narica*), which raids bird nests, had increased, while the big cats had disappeared (studies by Emmons in Sarawak Forest Department 1999). Also, ground dwelling birds and birds with a short life-span had disappeared, while many canopy dwelling species seemed to thrive. It has been suggested, that the disappearance of the big cats allowed the increase of the mid-size predatory mammals, which in turn heavily prayed on ground-dwelling birds, while the effects were heaviest on species with a high generation turn over. This suggests that some species may take some other species in their wake when they disappear: secondary extinctions or cascade effect (Ryan and Siegfried 1994). It could be argued, however, that this species inter-dependence is part of the species area relationship, which causes the occurrence of more species in larger areas. The reverse effect should thus occur when ecosystems become reduced in size, and for that reason, no numerical consequences are drawn from this effect in this document.

### Variation in the exponent of the species-area curve

This document builds heavily on the species-area curve and on an optimistic low value of the exponent $z$. First, how responsible is that? With regard to the first question, there is no doubt about the mechanism that the number of species increases with the size of an ecosystem. The power-formula achieves that, and has been used for more than 80 years for determining the minimum size of relevés, while it has been proven to work. Therefore, building criteria from this formula is responsible, though speculative because not proven in complex ecosystems. What if $z$ is much larger, as Plotkin et al. (2000) suggest? There is agreement among biologists that $z$ is smaller for mainland conditions than for island conditions, where the factor commonly is believed to be about 0.35 for the latter and smaller for mainland conditions.

**Table 7**: Some $z$ values for different island taxa

| Taxon | *Z* values |
|---|---|
| Breeding land birds on West Indian Islands | 0.24 |
| Bats on West Indian Islands | 0.24 |
| Reptiles on West Indian Islands | 0.38 |
| Recent terrestrial mammals on West Indian Islands | 0.48 |

Mammals have much lower dispersal power among island dwelling fauna than flying animals. Therefore, their $z$ value is much lower (Prins 2002).

It is assumed that on continental conditions $z$ is significantly smaller, or it would not make sense making a point of it. The value of z varies per taxon and is reversely related to the dispersion power of taxa (Prins 2002) the dispersal power of terrestrial species on continents is better than on islands, which is reflected in lower $z$ values for flying organisms than for walking organisms. Given some of the $z$ values for island situations in Table 7: "Some values for different island taxa", logic would suggest that for continental situations the $z$ factor might indeed be lower than 0.2, with estimates between 0.12 and 0.19 (Connor and McCoy 1979, Reid 1992) for subsamples of continuous habitat, but this is probably subject to further analysis. Ney-Nifle and Mangel (2000) observe that $z$ varies with the location and shape of the area conserved, depending on the distribution of the species concerned. Table 3 provides the percentages of species conserved for different percentages of area preserved. It is left up to the reader to speculate what proportions of the world's biodiversity may be conserved, if the "Bali" recommendation of setting aside 10 percent of the land mass of every country as protected area be successful.

**Table 8**: **Percentage of Species conserved for different z values**[30].

| Percentage Area Conserved | Percentage Species Conserved $Z = 0.15$ | Percentage Species Conserved $Z = 0.2$ | Percentage Species Conserved $Z = 0.3$ |
|---|---|---|---|
| 50 | 90 | 87 | 81 |
| 30 | 83 | 79 | 70 |
| 20 | 79 | 72 | 62 |
| 15 | 75 | 68 | 57 |
| 12 | 73 | 65 | 53 |
| 10 | 71 | 63 | 50 |
| 5 | 64 | 55 | 41 |

In this document, the differentiation of species assemblages is based on rather detail-defined ecosystem classes, which favours the capture of more species than would be the case when using much coarser defined ecosystems. The approach of seeking representation of each ecosystem several times per country, leads to geographical variation, within the same ecosystem, which would result in the selection of further variation in species assemblages; this is probably one of the factors that contributes to the shape of the species-area curve. By passing from one region to the next, more species would be included, than would be the case if one would expand within a single area of that same ecosystem. This has been corroborated by S. Mori (pers. com.), who has an extended database for French Guinea. The combined approach of search for diversity in species assemblages by selecting ecosystem differentiation and geographical spreading would always lead to further maximisation of species numbers.

A worldwide target of protecting somewhere between 10% and 20% of the land as protected areas is probably the maximum feasible; the integrated method of differentiation in this document offers the most detailed reasonably rapid method possible with present day techniques. If by the end of the day, **z** turns out to be higher, it is likely that the world will lose more species.

## 3.6. SPREADING OF EXTINCTION RISKS

### Buffering against disasters

In previous chapters, the survival chance of isolated populations was analysed from the point of view of gradual extinction – as well as occasional neo-invasion - through stochastic processes. The likelihood of overwhelmingly powerful events that would kill most of an entire population is real and needs careful consideration. Events that threatened many species simultaneously and destabilise an entire ecosystem through habitat destruction include hurricanes, fires and human trespassing leading to habitat destruction; species-specific disasters include aggressive poaching and virulent diseases. Den Boer (1968) used the term "spreading of risks" for the survival strategies in Carabid Beetle populations, and analogically Vreugdenhil (1992) looked for risk spreading strategies for whole ecosystems in the sense of simultaneous eradication of a variety of species belonging to an ecosystem. In dialogue with P. den Boer (pers. com.) it was argued that the theoretical ideal level of protection for ecosystems would be the occurrence at 5 different locations of any given ecosystem in a national protected area system.

The argumentation is as follows: Statistically, stochastic extreme conditions tend to occur in groups of maximally of three or four events. In this context, such extreme conditions may be a mix of mankind induced and natural disasters that threaten the ecological nature of the ecosystem and the survival of the species that depend on it. Five occurrences being the first higher number of representation of an ecosystem in a protected areas system would provide a significantly higher level of security against extinction of the species depending on that ecosystem. In practice, such level of representation is not feasible for all ecosystems. At the same token, the vast majority of species in a national protected area system are not restricted to the country in question, and are likely to be protected in neighbouring countries as well. Therefore, the spreading of risks against extinction by disaster is still well secured if an ecosystem occurs in three different protected areas, particularly if the same ecosystem would also occur in a neighbouring country or if an ecosystem occurs in smaller – non-mappable – patches in other ecosystems. Obviously, some ecosystems may only occur once or twice in the country, and depending on ecosystem size and availability of the land, 100% representation as well as area coverage in the protected areas system may need to be targeted, but one and two occurrences may be considered under-represented.

[30] An Excel file that allows varying the values has been placed on the following Web page:

http://www.birdlist.org/nature_management/national_parks/national_parks_systems_development.htm .

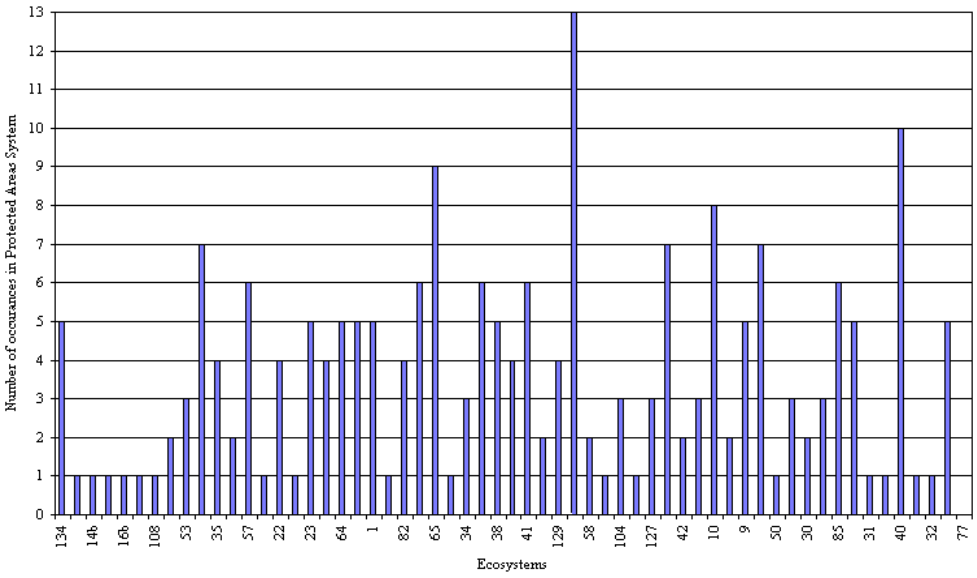



**Figure 10: Number of occurrences of each ecosystem in the accepted protected areas system in Honduras**. A number of ecosystems is unique in the country and could only be incorporated once. In those cases, the entire ecosystem is incorporated in the Protected Areas System.

**Buffering against climate change and other human induced change extremes**

Climatic change has a tremendous effect on the distribution and survival of species as well as on speciation, as has been so convincingly demonstrated by van der Hammen and Hooghiemtra (e.g. 1996, 2002). Rosenzweig (1999) somewhat dramatically warns that if we warm our globe a degree or three and displace the essential climates of the world's nature reserves that they can no longer preserve anything. When the predicted climatic change occurs, many reserves will be reigned under different climate conditions, thus destabilising the ecosystems in the reserves. Many species will lack opportunities to redistribute themselves by following their required climatic conditions and will go extinct. The process of change is likely to be very fast in geological terms, and species with limited mobility would be at a disadvantage as the mechanisms of their redistribution would be too slow to follow the changing climatic patterns. When the world's terrestrial biodiversity be intellectually and neatly compressed on a surface of somewhere between 10 and 20%[31], ecosystems will be islands among intensively used production areas. The destabilising effects of climatic change would be considerably more severe as many – even mobile –species would be captive within their protected areas unable to bridge their restricted distributions to areas where climatic and other ecological conditions favourable to their survival would develop or persist. Biological corridors help some species – particularly mobile fauna -, but are likely to be ineffective for the needs of redistribution of the vast majority of immobile species. If the world would successfully capture the majority of species in a worldwide system of national protected areas systems, climatic change is bound to have a very significant toll, of a yet unforeseeable magnitude, but many reserves will still support assemblages of interesting wild species as the population levels of the remaining adaptive species will adjust to the new climatic regimens and ecosystems stabilise under the new ecological terms.

Biological corridors pose major financial strains on conservation funding and it may be wise to take lessons from paleoecological processes of species survival and speciation. In South America, mountains have played a major role in species survival, speciation and adaptation of distributions to new conditions (for these processes see e.g. van der Hammen and Hooghiemstra 1996, 2002). Particularly one must search for the conservation of areas with internal conditions that would allow short-distance climatic variability and adaptability: protected areas with significant variety in elevations. As global warming is expected to result in higher temperatures and lower rainfall, mountainous areas would facilitate that at least a part of the species of an area could find suitable conditions at higher elevations at relatively short distances. Climatically, short corridors that bridge different elevation levels would be far more effective buffers against species loss caused by climate change than generic biological corridors that connect areas of similar climatic composition over great distances.

Areas undergoing significant change will go through a process of major shifts in species composition, in which a part of the original species disappear, some may undergo a shift in dominance and some new ones arrive. It is impossible to predict what percentage of species may survive climatic changes, particularly not since we don't know yet the nature and the degree of change. The adaptability of many species will be tested. For highly mobile species and species with large ecological tolerance, survival will be more feasible. Particularly many medium-sized and large mammals and bird species of all sizes will be able to survive

[31] Both MICOSYS and BioRap have been finding required surfaces of somewhere around 15%., Vreugdenhil, 1992, DHV, 1994, Faith et al. 2001, Vreugdenhil et al. 2002.

given their ecological tolerance and/or their high mobility. Further, their larger sizes and higher societal affection favour management actions such as monitoring and financing of measures to support their survival.

With transport systems spanning the globe, more and more virulent pathogens and invasive exotic species get a chance to spread into new territories. Virulent diseases and invasive exotic species form very realistic and powerful threats to conservation. Virulent species particularly if spreading into new territories where host species have little resistance. Particularly on trees, they may have far fetching consequences, as they may cause major changes in the compositions of species assemblages of ecosystems. When pathogens pass geographic barriers, they may result directly or indirectly in the extinction of some species, particularly if their occurrence leads to physiognomic changes of the vegetation or the floristic composition of the tree layer of entire ecosystems. There is very little that can be done through strategic design of protected areas systems. In general, terrestrial invasive species are less successful in stable natural terrestrial ecosystems. The latter cannot be said of limnic ecosystems, where the introduction of predatory fish can reeve havoc in stable natural ecosystems.

**BOX 11: SOME CASES OF PATHOGENS WITH SEVERE ECOLOGICAL CONCEQUENCES**

One of the latest epidemics is the Sudden Oak Disease, caused by *Phytophthora ramorum*, a very deadly fungus (Hoffman 2002), that not only kills oaks, but a large variety of hosts, including the California Redwood and other coniferous trees (Taugher 2002). An older case is the Dutch elm disease, caused by the fungus *Ophiostoma ulmi,* which is transmitted by two species of bark beetles or by root grafting. The American elm, *Ulmus americana*, is the most seriously affected of all elms and its position in forest ecosystem is rapidly diminishing (Stack et al. 1996). The disease has spread throughout North America and has destroyed over half the elm trees in the northern United Sates. A still older case, the Chestnut blight, *Endothia parasitica*, all but eliminated the American chestnut, a dominant tree that occupied an important ecological position in the forests of the Eastern USA (http://chestnut.acf.org/ 2002).

Finally, war and severe civil unrest are conditions of extremely high and usually unmanageable risk for conservation efforts. Peoples in state of war and famine usually (and understandably) abandon all interest in conservation until such times that peaceful conditions return, and little of the concepts of this document will work under conditions of social unrest and famine.

A different effect of global warming is the rise of the sea level. While in prehistoric times the sea level has always fluctuated, coastal marshes and swamps would always follow the new coastline, moving into new shallower water when levels fall, and being pushed backward into land that was beyond the reach of the sea when water levels moved up. Most wetland organisms are either very adaptive, very mobile or both and can readily adapt to such situations. But under current circumstances, their flexibility is no longer enough. The world's coastal lowlands are the densest populated part of the world, and almost everywhere, the land is in use right up to the influence of the seawater. When the sea level rises, people will try and mitigate the natural effect of the rising water with all the means in their possession, varying from small-scale hard edges, drainage systems to full-fledged marine dikes and sea defence systems. As a result, the graduallity of the transition zones sea-land is likely to become severely reduced, which will result in a reduction of the ecosystems that depend on those conditions, thus threatening some of the related species.

## 3.7.EDGE EFFECTS

Edge effects are not at all foreign to ecosystems. Wherever a big tree falls they may open a 'chablis' (Oldeman 1974), an open space in the forest, where there is a mixture of "opportunity" for light and edge loving species, thus increasing local species diversity. However, more dramatic openings in natural tropical forests also exist. During the selection of protected areas for Ecuador in the mid-1970s, when 80% of the Amazon watershed of Ecuador was still covered under untouched forests, patches of forest with all trees fallen down were observed during reconnaissance flights. The sizes of those patches could easily be many dozens of hectares in which all the trees were mysteriously "knocked over", in a way very distinct from forest clearing for agricultural purposes. Also observed were good sized patches of recovering forest – heavily clad under thick carpets of vines – in areas where human settlement was still absent. Those patches in the Yasuni watershed looked very distinct in shape from the typical clearances made by the native Indians, the Waorani (population then believed to be at 500, J.A. Yost, pers. com., J.F. Duivenvoorden et al. 2001). Those observed deforestations are attributed to extremely violent, highly localised storms with extraordinary heavy rain and very high wind velocities that frequent the area. In Central America, the paths of infamous hurricanes can be marked by large-scale defoliation, deformation of trees and partial tumbling of trees. As sizeable patches of natural deforestation appear natural in the neotropics, one may expect natural responses to such conditions, including the development of edge effects. This means that forests can continue to function as forest ecosystems, even if their edges are abrupt and lack a bufferzone. In such cases, organisms in the transition zone or edge will respond to the situation of the edge, such as growing lower branches as a response to the increased light, trees perished under the new conditions may be replaced by pioneering species. Organisms with a preference for edge conditions will move in, while others that need mature forest conditions will withdraw from the edges.

The width of the edge effects is an important element of consideration, as they influence the effectiveness of the minimum sizes of ecosystems, particularly in the case of elongated patches. Wilcove et al. (1986) show that increase of predation on nests may extend from 300 to 600 m into the forest. Such transition zone may become quite relevant for small ecosystems or ecosystem fragments at the edges of protected areas. The zone may be narrower in ecosystems where organisms are already resilient to harsher conditions such as higher elevation ecosystems or along ecosystems with higher ecological dynamics. In general, it would be wise to discount a 500 m zone along the transition from a typically small ecosystem to agro-productive systems when evaluating compliance with the minimum size criteria.. In the case of open areas with important plains dependent species (mud flats with shore birds, steppe ungulates), the edges may be much wider and possibly stretch out over a kilometre, in the case of visible human activities.

**BOX 12: Some remarks on "climax" ecosystems**

In this document the use of the term climax vegetation or ecosystem has been avoided. Climax conditions assume a rather stable situation in which very little change takes place. Oldeman (1990) argues convincingly that vegetations – and the related ecosystems in the context of this document – don't occur as such. Coining the term forest eco-unit, he recognises that structurally homogeneous eco-units are not necessarily even-aged, and recognises four phases of aging of a forest:

- Innovation phase;
- Aggregation phase;
- Biostatici phase;
- Degradation phase.

These natural age classes occur through the forest as natural mosaics. Besides these natural processes of aging, other processes of forced rejuvenation take place in forest ecosystems, caused by intense disruptions in the most common conditions, which may be called natural disasters. These occur far more often than we are inclined to think; they include hurricanes and gales, lightning fires, outbreaks of diseases, flooding and small – yet significant – brief climatic variations. Similar phases of development occur in other physiognomic vegetation types as well, e.g. European heath lands (*Callunis vulgaris*) and reed (*Phragmitis communis*) swamps.

## 3.8.BIOLOGICAL CORRIDORS

Over the past decade, conservationists have been promoting the creation of biological corridors (e.g. IUCN 1998) with the world's most pronounced case of the Meso-American biological corridor connecting the Americas. Biological corridors are – usually narrow – areas between protected areas in which some natural habitat or physiognomic vegetation structure remains. The objective of biological corridors is to connect the populations of species in protected areas that are otherwise separated by production land-use.

Terrestrial biological corridors between pristine forest ecosystems will often consist of agro-productive systems in which some arboreal physiognomic structure is maintained (e.g. shade coffee and agro-forestry). In such anthropogenic ecosystems, only fractions of the species survive whose populations the corridor is supposed to connect. Primarily high mobility species will benefit from such connectivity, as they may temporarily bridge unfavourable habitat in search of new habitat or a mate. In the humid tropics, an inhabited terrestrial biological corridor with mainly intervened arboreous cover – like shade coffee or agro-forestry plantations - provides connectivity to those species that can at least temporarily survive under those intervened conditions and that are mobile; that is a very limited selection of species compared to the ones that live in the connected natural ecosystems. Strong flying insects generally don't need biological corridors as they can fly across unsuitable areas, while weak flyers would fall in a corridor that is no longer their habitat and where they can't survive. Hence, primarily medium sized and big mammals benefit from non-pristine biological corridors. Most plants and flightless and poor-flying arthropods will be unable to benefit from non-pristine biological corridors in the humid tropics. Of course on both ends of the corridor, the habitats must be suitable for a species to migrate successfully. That means that biological corridors between strongly different ecosystems are less useful, but they may serve species with large area requirements and low ecosystem selectiveness in casu, medium sized to large animals.

In anthropogenic ecosystems as well as ecosystems with open physiognomic structures (e.g. savannahs, prairies, marshes, tundras), probably more species may benefit from biological corridors, as many of those species have been selected to survive stress factors, which make them apt to survive in the less-than-optimal conditions of corridors. Many of those species are relatively mobile or have efficient dispersal mechanisms. Therefore, biological corridors are probably more effective and therefore, desirable in countries where remaining nature primarily consists of open landscapes (often resulting from human activities), e.g. (not exhaustive!), Europe (van Opstal 2000, Foppen 2000), savannahs and prairies with (migrating) large mammals in Africa, Asia and some areas in North America. Vos (1999) observes that connectivity is reversely related to the distance between suitable habitats. The further protected areas are separated from each other, the fewer the species that may benefit from the availability of a biological corridor.

Most major ecological networks (protected areas systems connected by biological corridors) are located in Eurasia; The world's most pronounced biological corridor is the Mesoamerican Biological Corridor connecting nature in all countries from Southern Mexico to Panamá (Bennet and Wit 2001), which is an international effort among the participating countries with multi-focussed financing from many international financing institutions.

Although biological corridors may theoretically contribute to enhance the viability of small populations, one must be cautious that their creation does not lead to competition with the funding of the core protected areas. In **poor** countries where the mere protection of vital ecosystems is still subject to serious feasibility challenges, the connection of the protected areas of a system with biological corridors may need to be postponed until the conservation of the core system has been well-established unless the financing may be achieved through funding from sources other than for biodiversity conservation. Under well-established we understand that at least the threats of illegal invasion and aggressive poaching has disappeared.

When ecological connectivity is not feasible, human interference may be required in the form of artificial exchange of individuals among populations and assisted re-stocking, which has become common practice in Southern Africa (H.H.T. Prins pers. com.). The smaller the area the more intense management actions may be required.

# 4. PROTECTED AREAS SYSTEM COMPOSITION

## 4.1. MICOSYS, A PROTECTED AREAS SYSTEM ANALYSIS TOOL

In 1992, the World Bank formulated a study (Vreugdenhil 1992), to:

- "Propose a criterion/methodology for evaluating whether the existing system of national parks and biological reserves achieve their goals, namely of protecting biodiversity;
- Assess whether the existing parks and biological reserves are representative of Costa Rica's ecosystems and if not, to what extent (e.g. total biodiversity covered);
- Describe and evaluate the relative biodiversity protection value of each protected area (e.g., on the basis of their degree of endemism) along with natural protection characteristics of these areas to assist in the prioritisation of a potential schedule to maximize the biodiversity protection effect of the system in the most cost-effective manner;
- Assess whether the protected areas are ecologically viable or if they (a) need to be expanded; (b) there is need for biological corridors linking parks and reserves; (c) whether ecological corridors are socially and economically practical."

To carry out his task, Vreugdenhil (1992a) designed a spreadsheet-based programme that he called MICOSYS (1992b). Its acronym stands for "Minimum Conservation System" and was designed to (1) help identify a country's biodiversity representation and gaps in an existing protected areas system and to, (2) model the composition of protected areas systems for the durable conservation of the vast majority a nation's species and (3) estimate the investment and operational costs of the selected system. The spreadsheet compares areas on the basis of representation of ecosystems, species of special concern and socio-economical and cultural variables.

MICOSYS was one of the first computer-based protected areas analysis tool to be developed and has been used in a variety of countries. Once the programme has been used to identify a "minimum conservation system", it may serve in the design of different alternative models with higher levels of conservation security. It can be used for a variety of analytical tasks that require the mutual comparison of protected areas, like:

- Relative32 weighting of protected areas for the purpose of declaring new lands or for management and financing purposes;
- Presence/gap analysis of ecosystem33 and/or species representation in protected areas systems;
- Cost estimates;
- Budgeting;
- Monitoring and Evaluation practices to evaluate management success or setbacks.

The programme was originally developed as a simple and transparent programme in a "Lotus-123" spreadsheet using the basic FAO principles for protected areas selection and categorisation criteria for Latin America (FAO 1974, Miller and Thelen 1974, Putney and DPNVS 1976). Comparative weighting of the areas takes place on the basis of a selection of ecological, taxonomical and socio-economical variables. Each variable can be assigned a value or algorithm on the basis of a professional judgement; thus, each value by its very nature is subjective. But once established, the processing of each parameter is carried out mathematically and performed identically for each variable and each area. As the parameters become numbers, the MICOSYS facilitates the paradoxical exercise of "adding apples and oranges". In the end it comes up with a numerical score for each evaluated area, which has come about by a consistent computing method. Such scores allow relative comparisons between the different areas. Of course, those values are indicative and should not be used in an absolute sense; e.g. a value generated for a protected area in Costa Rica cannot be compared to the value of an area in neighbouring Nicaragua, which has been generated from different data. In the following paragraphs we use the case of Honduras, as this has been the latest application. Please note that the data of that country only serve as an example of the programme's functionality. It is not a presentation of the Protected Areas system of Honduras.

The programme has been organised into seven main Sheets[34]:

**Sheet A**:General data / Datos generales;
**Sheet B**:Costs per area / Costos por area;
**Sheet C**:Costs of the system / Costos del sistema
**Sheet D**: Quantification of characteristics / Cuantificación de característicos;
**Sheet E**: Sizes of Ecosystems per area in ha / Tamaños de los Ecosistemas por Area en ha;
**Sheet F**: Ecosystem scoring per area / Valoración de ecosistemas por Area;
**Sheet G**: Scoring of species of special concern / Valoración de especies de preoccupación especial.

On the sheets are tables, numbered in Roman letters; Sheet D has 3 distinct tables.

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[32] Relative refers to the ability to mutually compare areas in the same weighting process. The system does not develop absolute or independent values.

[33] This is the process of identifying and classifying the various elements of biodiversity, then examining the existing and proposed protected areas on the presence or absence of the different biodiversity components (Burley, 1988). Nowadays, most common elements in the process are plant communities and endemic species.

[34] http://www.birdlist.org/nature_management/national_parks/MICOSYS_Honduras.xls):

The programme has evolved and matured through its application in several other World Bank, IDB and UNDP project formulation assignments. In 1994, a full application by a consultant team[35] (DHV 1994) was carried out in Belize, involving ecosystem mapping and MICOSYS based PA protected areas system analysis. In Honduras (Vreugdenhil and Archaga 1997), Nicaragua (Cedeño and Vreugdenhil 1996) and Panamá (Vreugdenhil 1998), MICOSYS was used to estimate system costs for World Bank/UNDP/GEF/IBRD-loan project formulations. In 1996, the programme was converted into, Quattro Pro and in 2002, it was converted to run under MS Excel. For full details of its functionality one may read the manual (Vreugdenhil 2002b), which is downloadable (see Chapter 1.3).

The programme is based on the premise of Article 8. on "*In Situ* Conservation" of the CBD, which requires its Parties to "establish a system of protected area" … "to conserve biodiversity". To that end, it requires qualitative, quantitative and distribution information of the biodiversity of the country under study. In Chapter 2, we have seen that ecosystem maps provide the geographically more even-handed information on partially different assemblages of species based on compound information of physiognomic, ecological and – if available – biogeographical and sometimes information of some species of special concern. This facilitates the calculation of sizes of the different ecosystems, which in turn, allows proportionate quantification of the biodiversity resource, e.g., if a nation's ecosystem type occurs in only three locations of respectively 700 ha 200 ha and 100 ha, we may assume that 70 percent of the species assemblage of that ecosystem is located in the first location.

## 4.2.QUALIFYING AREAS

The definition of a protected area adopted by IUCN is: An area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means Although all protected areas meet the general purposes contained in this definition, in practice the precise purposes for which protected areas are managed differ greatly. The following are the main purposes of management:

- Scientific research
- Wilderness protection
- Preservation of species and genetic diversity
- Maintenance of environmental services
- Protection of specific natural and cultural features Tourism and recreation
- Education
- Sustainable use of resources from natural ecosystems
- Maintenance of cultural and traditional attributes

[35] The team involved Rob Beck, Susan Ironmonger, Roger Wilson, Niek Bech and Daan Vreugdenhil, as well as many Belizans.

**Categories of Protected Area**

- IUCN has defined a series of protected area management categories based on management objective. Definitions of these categories, and examples of each, are provided in Guidelines for Protected Area Management Categories (IUCN, 1994). The six categories are: CATEGORY Ia: Strict Nature Reserve: protected
- area managed mainly for science. Definition: Area of land and/or sea possessing some outstanding or representative ecosystems, geological or physiological
- features and/or species, available primarily for scientific research and/or environmental monitoring.
- CATEGORY Ib: Wilderness Area: protected area managed mainly for wilderness protection. Definition:Large area of unmodified or slightly modified land, and/or sea, retaining its natural character and influence, without permanent or significant habitation, which is protected and managed so as to preserve its natural condition.
- CATEGORY II: National Park: Protected area managed mainly for ecosystem protection and recreation. Definition:Natural area of land and/or sea, designated to (a) protect the ecological integrity of one or more ecosystems for present and future generations, (b) exclude exploitation or occupation inimical to the purposes of designation of the area and (c) provide a foundation for spiritual, scientific, educational, recreational and visitor opportunities, all of which must be environmentally and culturally compatible.
- CATEGORY III: Natural Monument: protected area managed mainly for conservation of specific natural features. Definition: Area containing one, or more, specific natural or natural/cultural
- feature which is of outstanding or unique value because of its inherent rarity,
- representative or aesthetic qualities or cultural significance. CATEGORY IV: Habitat/Species Management Area: protected area managed mainly for conservation
- through management intervention Definition:Area of land and/or sea subject to active intervention for management purposes so as to ensure the maintenance of habitats and/or to meet the requirements of specific species.
- CATEGORY V: Protected Landscape/Seascape: protected area managed mainly for landscape/seascape conservation and recreation. Definition: Area of land, with coast and sea as appropriate, where the interaction of people and nature over time has produced an area of distinct character with significant aesthetic, ecological and/or cultural value, and often with high biological diversity. Safeguarding the integrity of this traditional interaction is vital to the protection, maintenance and evolution of such an area.
- CATEGORY VI: Managed Resource Protected Area: protected area managed mainly for the sustainable use of natural ecosystems. Definition:

Area containing predominantly unmodified natural systems, managed to ensure long term protection and maintenance of biological diversity, while providing at the same time a sustainable flow of natural products and services to meet community needs.

- CATEGORY UA: Where the site does not meet the internationally recognised definition of a protected area, application of a management category is not appropriate. This is indicated as category unassigned (UA) in UNEP-WCMC protected area lists.

It is important to make a few observations regarding protected areas categories. In principle, the categories I-IV all have biodiversity conservation without consumptive use as their primary objective. This is less clearly so with categories V, VI and UA. When reviewing the new data of the protected areas database of WCMC-UNEP (unpublished and preliminary data 2003), many areas from their nationally defined categories appear to belong in these latter IUCN categories. Depending on the ecosystem, extractive or consumptive use, may significantly alter the species composition. Therefore, categories V, VI and UA cannot give be considered a priori areas that warrant conservation of the species assemblages and ecosystems under their conservation status. Even if within such areas the ecosystems in question are zoned for non-extractive conservation, the instrument of zoning often does not have the same kind of legal and durable robustness as a gazetted status under categories I-IV. For some ecological criteria that may not be all that important. For instance, category V, VI and UA areas usually can provide excellent shelter to species in need of large areas and thereby can make great contributions to the conservation of the world's large predators. Dynamic ecosystems – many aquatic ecosystems – are quite resilient to some forms of resources use without experiencing major shifts in species composition. Whether or not, or which parts of category V, VI and EU areas should contribute to the conservation of a nation's heritage of species and ecosystems should be an important part of the considerations to be made in developing a comprehensive system of protected areas for the conservation of biodiversity and ecosystems.

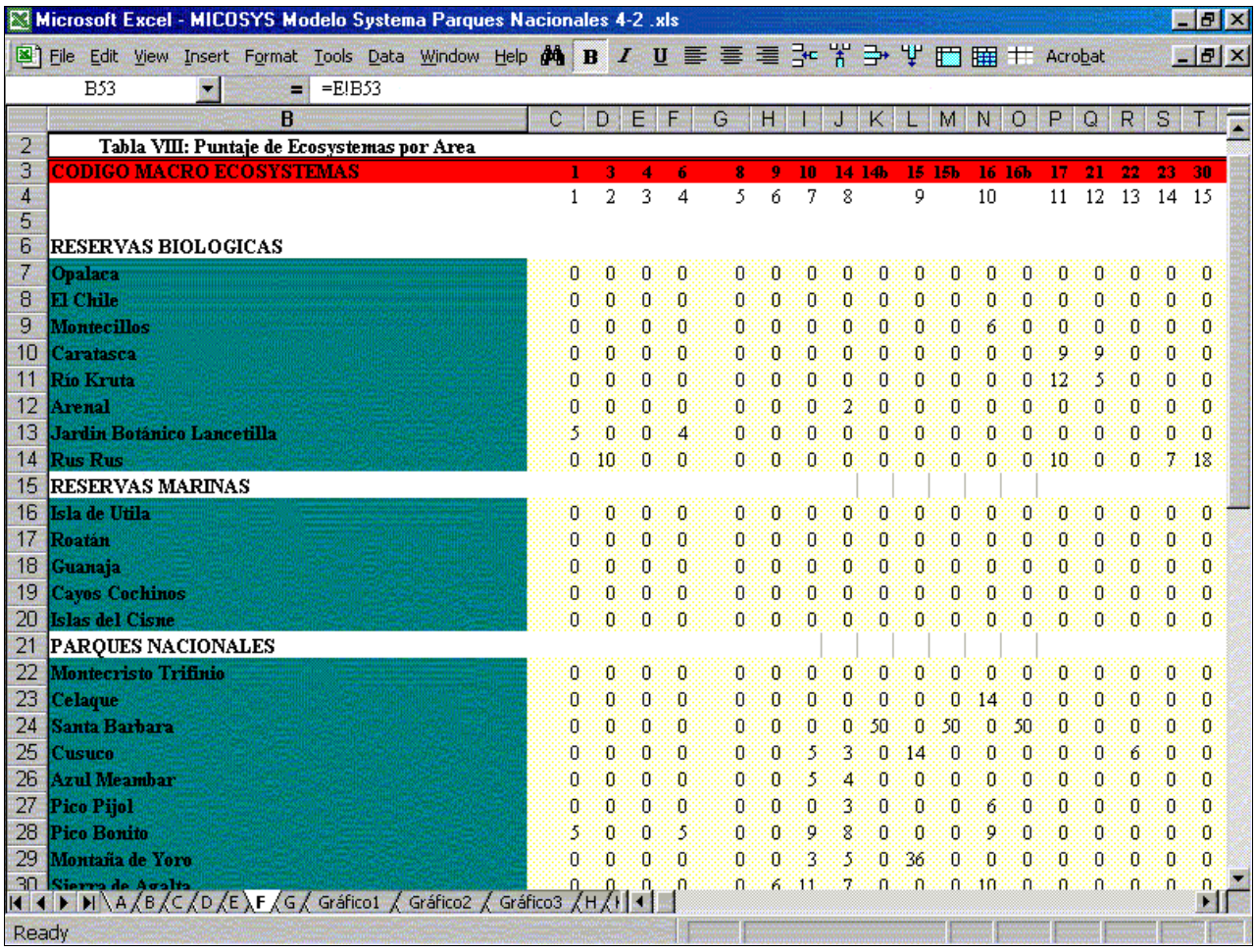



**Figure 11**: Ecosystem scores in the MICOSYS application for Honduras . The scores are based on a combination of proportion of the size as occurring in the country and proportion of occurrence in the protected areas system.

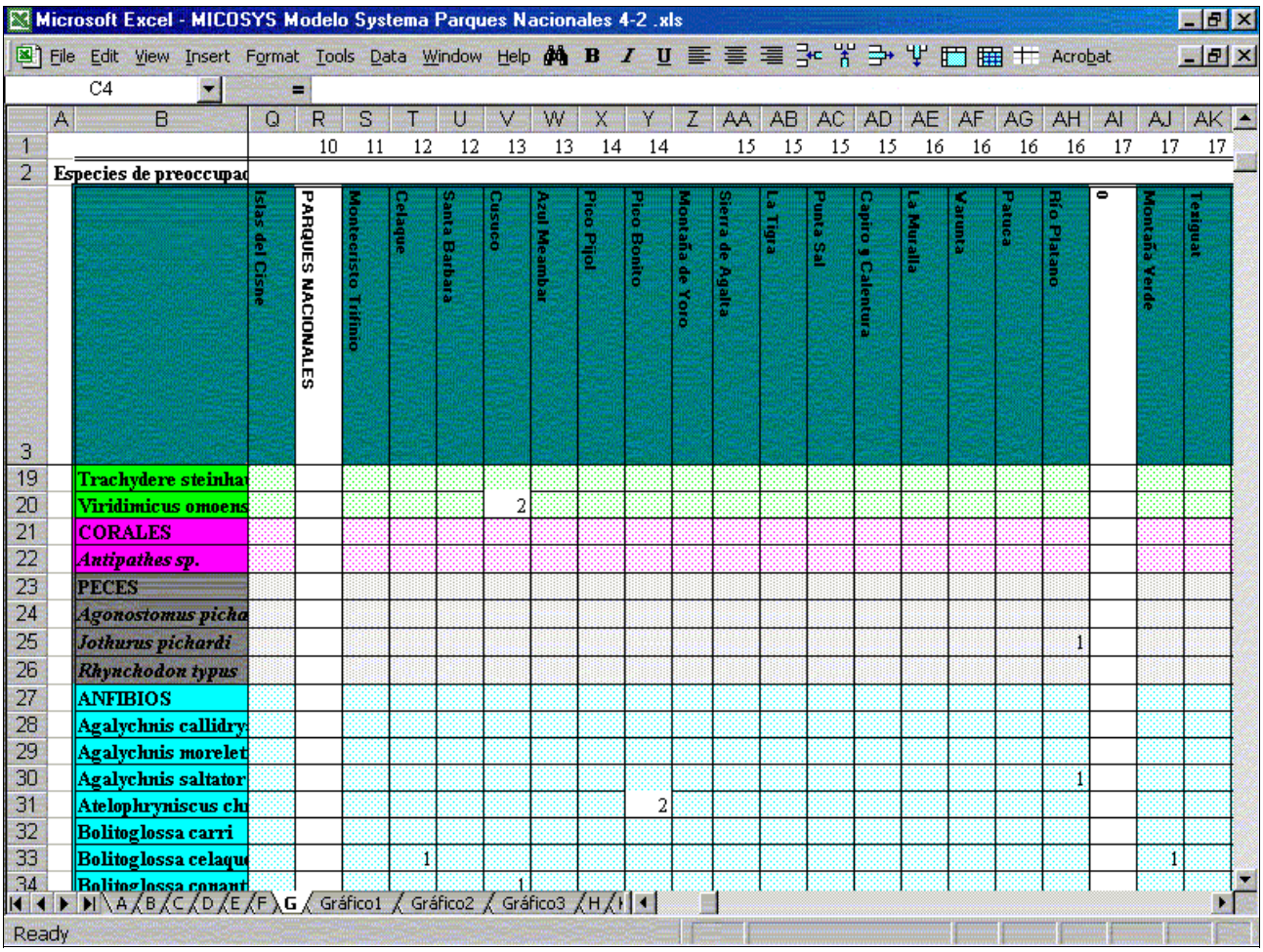



**Figure 12: Representation of Species of Special Concern in MICOSYS**. Species of special concern are entered in all the areas of their know distribution. Limited distribution species area given a double value.

The programme requires an ecosystems map in a GIS format to calculate polygon sizes of ecosystems. Also, there must be an accurate digitised map of the existing protected areas. The polygons of the ecosystems and the protected areas must be combined (overlaid) to calculate which ecosystems are protected in the system, how often, where and how much in each protected area. Similar actions may be performed for other geographical data, such as productive (e.g. for drinking water or hydroelectricity) parts of watersheds in protected areas and private land-ownership.

## 4.3. SCORING CHALLENGES

While it has become popular in conservation circles to downplay the importance of species-based data, Faith (2001) believes that this is a fundamental weakness that needs to be corrected (See also Mittermeier et al. 1999). Article 8 clearly makes biodiversity the first selection criterion of a national protected areas system for compliance with the commitment undertaken by all signatories to the CBD. Therefore, species-based biodiversity comparison and validation criteria occupy an explicit and important part in the application of MICOSYS. Yet, even though the primacy of biodiversity and natural heritage values in ascribing protected area status is pre-eminent, many protected areas also serve to provide environmental services[36], notably tourism, recreation, production of drinking water, research and education. Where appropriate, the programme assigns the potential of the most common services a value. The programme has been designed to be extremely flexible [37], and there is no limitation to either the number of factors to be weighted or the relative value attributed to a factor. Factors of validation as well as relative weighting between factors need to be established; additional factors of validation may need to be added by inserting a column to the programme.

Some elements must be weighted that must be considered as threatening or negative elements in the evaluation and the programme may assign a negative value to such conditions. By default, the programme has been set up to weigh the following parameters of the areas of a national protected areas system:

- Size of the reserves (Sheet A, Table I);

[36] An extensive review of the functions of nature has been made by De Groot, 1992.

[37] Although designed for protected areas of IUCN categories 1 to 4, MICOSYS allows the application for much broader concepts than biodiversity conservation only and may be applied to other protected areas categories as well.

- Size of the land/water under cultivation (Sheet A, Table I);
- Tourism value (Sheet D, Table VI);
- Environmental education (Sheet D, Table VI);
- Size of economically used parts of watersheds (Sheet A, Table I);
- Ecosystems (Sheets E, Table VII and F, Table VIII);
- Geomorphologic highlights (Sheet D, Table VI);
- Extraordinarily scenic landscapes (Sheet D, Table VI);
- Archaeological remains (Sheet D, Table VI);
- Species of special concern (Sheet G, Table IX).

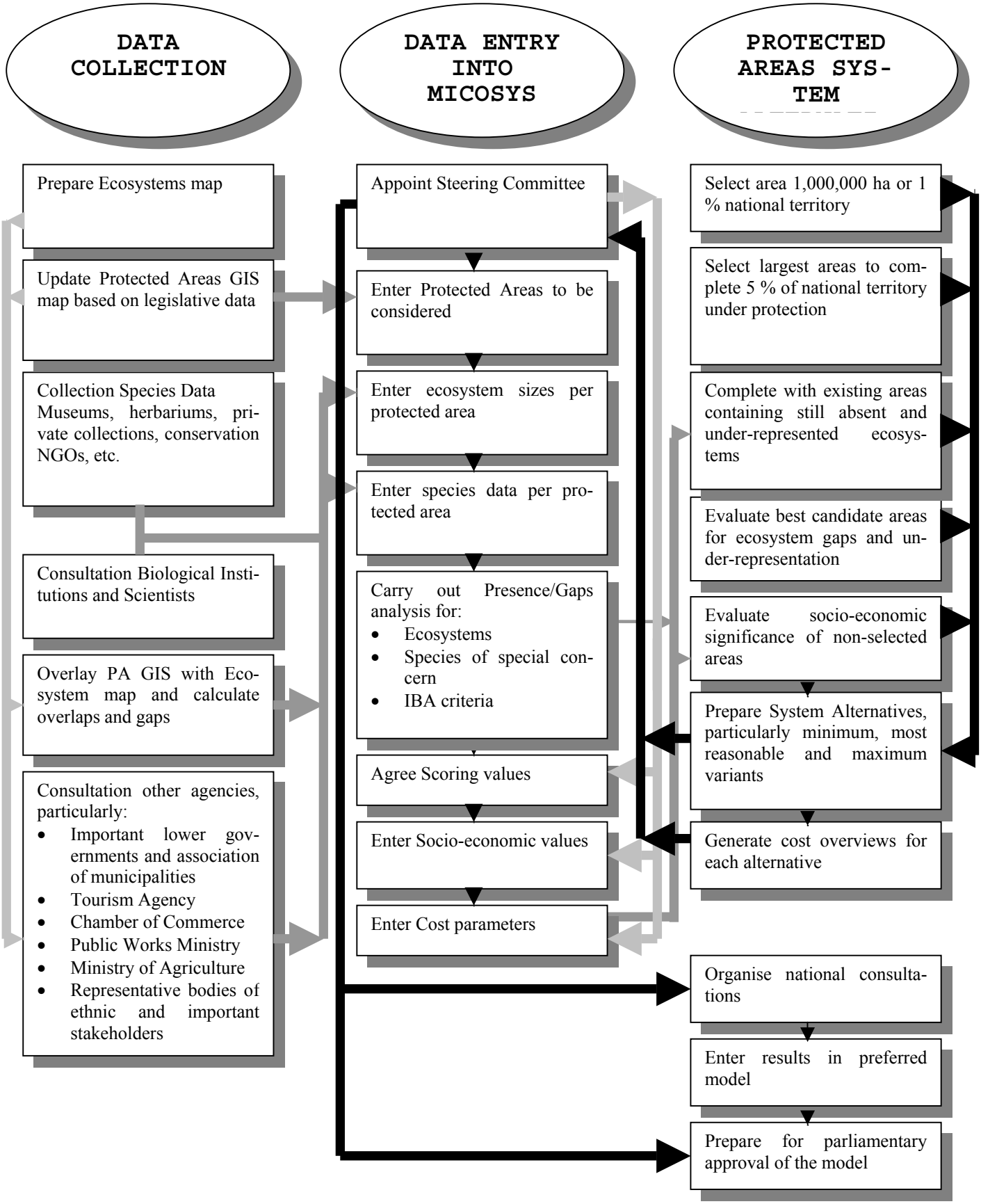
Standard, MICOSYS comes with a pre-set set of values, so that users may conveniently start using it. However, relative importance will vary from country to country, and an essential part of the evaluation process is the review of the weighting factors. This, and the entire process of protected areas system planning and evaluation should preferably be carried out under the supervision of a broadly composed **steering committee** involving a representation of conservation gremia such as universities and conservation NGOs, as well as indigenous groups where relevant. The different moments of decision-making should be carried out through ample and broad consultation through workshops.

The principle of operating MICOSYS in a simple spreadsheet has never been abandoned. It can be applied by national conservation technicians without GIS background to walk through a consistent process of weighting different values applied to their protected areas. Having the weighting process stored in spreadsheet files, the evaluation process remains highly reproducible over time. When in the future more data become available, re-evaluations may be imposed on previous ones by opening previously produced files and making the changes. As this requires no specialised software knowledge, re-evaluations can be applied by regular in-house technicians of the protected area administration.

This document does not review the entire procedure and sets of instruments and information required for the establishment of a protected areas system; only the biological requirements in a context of other important uses of protected areas. MacKinnon et al. 1986 provide a broad review and many national strategies for biodiversity conservation have amply dealt with the issue (e.g. the Biodiversity Conservation Action Plan for Mongolia, MNE, 1997) as well as the IUCN/WCPA Best Practice Protected Area Guidelines Series mentioned earlier. This document merely deals with the technical selection of biodiversity to a national system, while also considering some of the most common direct benefits for society. If as a result of the analysis, an ecosystem has been identified to be underrepresented, and its addition has become desirable for a chosen model, a detailed holistic proposal study is required, including trade-off and opportunity costs analysis. Such studies are necessary as separate follow-up exercises for the legal and administrative creation of the addition.

As almost all countries in the world now have protected areas, the system starts out from existing areas and identifies the gaps in ecosystem and species representation that would need to be closed, to provide a comprehensive *in situ* conservation system. MICOSYS helps identify the nature of these gaps, but it cannot define their geographic location and dimension. The latter needs to come from GIS systems and databases.

**Flowchart 2: Primary steps in a protected areas system composition process.**



**BOX 13: SOME OTHER PROTECTED AREAS SYSTEM ANALYSIS PROGRAMMES**

Since the creation of MICOSYS several other computer programmes have been used for weighting protected areas systems. ABC (1997) developed a GIS-based system called Biological Information Management Sys-tem (BIMS). It used three scoring indices to review conservation effectiveness in the Indo-Malayan Realm:

**Biodiversity Index**: provides a more objective evaluation of the biodiversity importance of individual countries and biogeographical units;

**Conservation Index**: evaluates the effective conservation effort being applied currently in relation to what should be done. It is the ratio of **Equivalent Area Protected/Expected Area Needed for Protection**, a dynamic score that assesses the degree to which a country or biounit is meeting international conservation standards. The index can be plotted over time to show a country's performance, rather like a financial index;

**Opportunity Index**: determines the priority for further action in different countries.

It is not clear if the system would work for evaluating individual national protected areas systems.

A biodiversity assessment and planning study for Papua New Guinea was published in 2001, which used the "BioRap" method (Faith et al. 2001). BioRap was originally designed to find sets of areas that fully represent biodiversity features. It consists of several specialised database, GIS and heuristic analysis tools. It not only evaluates biodiversity elements, but it also looks at economic aspects, such as opportunity costs, and trade-offs. The BioRap Toolbox was assembled under the first BioRap Project during 1994-95. This project was carried out under AusAID-World Bank funding, by a Consortium of four Australian scientific and techno-logical agencies: CRES of the Australian National University; CSIRO; the Environmental Resources Information Network (ERIN) and the Great Barrier Reef Marine Park Authority (GBRMPA). Like MICOSYS, BioRap departs from the premise that truly effective biodiversity conservation demands inventory, evaluation, planning and management. Its biological analysis heavily leans on individual species data from field-collections, which only play a more secondary role in MICOSYS. The method is very thorough, but it is a "high tech" programme; it requires considerable "non-biologist" inputs from database and GIS operators, something that has purposely been avoided in the programmes presented in this document.

The Nature Conservancy (TNC) had a heuristic programme developed by the University of California in Santa Barbara, (Secaira et al. 2001) named "SITES" . It is a MS-DOS programme interfaced with ArcView. Enticing as such advanced programme may seem at first glance, they have a serious downside: their functioning is based on complex mathematical processes that are incomprehensible for most users and therefore, they are not transparent. As these programmes are aides for policy development and decision taking, their complexity and intransparency render them less suitable.

More commonly, selections of ecosystems to protected areas systems or their evaluations have been based on expert evaluation (e.g. Putney 1976, for Ecuador, McKinnon and McKinnon 1987 for the first review of the Indo-Malyan Realm, Dinerstein 1995, with a follow up by Ledec et al. (not-publicised document 1996) for Latin America). The method for Latin America involved the following criteria:

- The area of each country and bio-geographical sub-division which is protected;
- Coverage in relation to species richness, centres of high biological distinctiveness or endemism and in relation to threats to "habitat";
- Management effectiveness in individual countries; and
- Consideration of adjacent land-use and critical "habitat" requirements.

The latter three criteria involved rather non-defined plural criteria, which seem difficult to detangle and weight. Regional evaluations are important for international financing agencies to review their internal effectiveness and assess which countries may need some extra attention. Nevertheless, one must be aware that national evaluations for the development of protected areas systems are far more important. Every nation is en-titled to conserve a sample of its national natural heritage, irrespective of its value from an international point of view. Furthermore, conservation programmes must primarily be carried out within the jurisdiction in force; usually belonging to a nation. In the case of trans-border species or ecosystems, actions must be taken separately in each individual country; this is recognised in the CBD, although management cooperation may be possible, e.g. Costa Rica and Panama carry out joint patrol missions along in the border region of La Amistad National Park. Thus conservation programmes should be primarily focussed on financing and assisting national programmes, while international programmes should primarily focus on programmatic synchronisation and efficiency in information acquisition and experience building.

Another methodology for weighting biological value of sites has been proposed in (Bennun & Njoroge 1999) and has been applied on Important Bird Areas in Kenya. In this method, sites are scored within all four IBA selection criteria. Scores are accumulated into a simple ranking system and then the ranks for all the criteria are combined to give a final level of importance for biodiversity. Every site is scored for all categories, whether or not the site qualifies under a given category. This helps to identify sites of highest biodiversity importance.

Site prioritisation based to identify most threatened IBAs has been carried out for Turkey. The following criteria have been collectively considered to identify most threatened IBAs in Turkey (Eken 2002): (i) species populations affected; (ii) irreplaceability of the impact of the threat and (iii) the surface area imposed by the threat,

## 4.4. DEVELOPMENT OF MODELS WITH DIFFERENT LEVELS OF CONSERVATION SECURITY

The creation of a system of protected areas involves the establishment of a set of limitations of land-use to be applied on the gazetted lands; particularly, the conversion of natural habitat into productive land needs to be prohibited, as well as non-regulated hunting and gathering. Applying such limitations upon lands involves opportunity as well as political costs, irrespective of the land-ownership or user-rights of the land. If lands are privately owned or owned by a specific community, certain limitation need to be enforced which may require compensation or purchase of the lands, often involving significant financial sacrifices. Usually, society as a whole has to bare those costs, and no society is politically or financially willing or capable to have unlimited areas set aside as protected area. The willingness of societies to set aside land (economists speak of opportunity costs) for the purpose of protecting biodiversity needs convincing justification. Therefore, conservation gremia need to select their areas efficiently and provide thorough justification for their selection.

Once established, protected areas need continuous attention, such as facilitation of visitation, monitoring and patrolling, activities that require staff, buildings and equipment. Each additional hectare involves additional management costs. Such costs will re-occur every year. Thus, by setting aside land for a protected areas system, a society assumes a permanent financial commitment to meet with the management requirements for their use and protection. This is another reason to compose protected areas systems efficiently both in territorial size and cost-efficiency, off-setting costs against a degree of biodiversity representation and a safe minimum standard of conservation (Ciriacy-Wantrup and Phillips 1970).

Within the conservation needs, there is somewhat of a conflict of interest between maximisation of species diversity and providing conservation security for the larger organisms. Many large organisms are rather habitat tolerant and merely need to be left alone in a vast area with the more common conditions of the region. Large areas, however, are very hard to acquire, and where available, they rarely contain all the ecosystems of a country. Maximisation of biodiversity requires that a broad variety of different ecosystems be protected. Staking out the required ecosystems in isolation would lead to a maximum diversity within the system at the smallest territory possible. Such system would consist of a collection of small reserves spread across the country with low survival value for large organisms. To meet the requirements of both large organisms and ecosystem variety, it is recommendable to follow a two-tiered procedure, based on size as well as ecosystem selection.

First, target maximum ecosystem stability in the protected areas system by selecting a minimum of 5% of any natural land in the largest possible units coarsely distributed across the nation, hoping to include most of the large-scale ecosystems. The largest area or complex of contiguous areas should ideally have a targeted minimum of 1% of the nation's territory or a minimum of 1,000,000 ha. Often the creation of large territories gazetted as protected areas requires international cooperation of nations joining areas along their borders. Any large area will usually include 10% or more of each of the more common ecosystems, as well as of one or a few less common ones. Particularly mountain regions undergoing such coarse selection procedures are likely to generate considerable ecosystem variation, given the varying elevation levels. From Table 8, we may read that under homogeneous conditions, 5% of the territory would capture more than 60% of the species if $z = 0.15$. Ecosystems occurring in 10% or more from their national territory would represent about 70% of their species assemblages. Assuming some high representation and some absence, a selection of large areas distributed across the country – although not fully homogeneous – would probably capture more than 50% of all the species that were historically present in the country and still a somewhat higher percentage of the presently still surviving species.

After the chance selection of ecosystems through the previous procedure, one should complement the system with absent or underrepresented ecosystems to meet with the following criteria:

- Encompass 2 to 3 examples of each ecosystem in different areas at or above its minimum size or as embedded ecosystems;
- Typically small terrestrial ecosystems should have a minimum size of 1000 ha plus compensation for edge effects where bordering non-protected land;
- Typically medium-sized isolated terrestrial ecosystems should have a minimum of 5,000 ha plus compensation for edge effects where bordering non-protected land;

- Typically large isolated terrestrial ecosystems should have of a minimum of 10,000 ha;
- national distribution missed in the first selection;
- Consider IBAs not yet selected through the previous selection criteria, using existing data.

For decades, biologists have engaged in the so-called SLOSS (Single Large Or Several Small reserves) debate, in which some argue that one needs a single large protected area to provide durable conservation. Other biologists argue that one needs several small ecosystems to capture as many species as possible. In this document we have made it clear that we need SLASS: Several Large And Several Small reserves; the former targeting maximum ecological stability and the latter targeting to complete the protected areas system with ecosystems and species absent in the large areas, thus maximising the national heritage of ecosystem and species diversity.

Complementary to the areas analysis, an analysis must be made of the **species of special concern** (SSP). Particularly the IBAs not yet selected otherwise should be considered, though not all may be included. In Honduras, the ecosystem selection procedure had already selected the vast majority of the known locations of SSP. In countries with high biodiversity, it will often not be possible to create a special area for each species of special concern in addition to the areas selected on the basis of the previous criteria and it must be accepted that some species just cannot be included in the system. Sometimes special site regulations may adequately protect a species, such as seasonal or local protection of the species in question. Occasionally translocating them to nearby protected areas with similar habitat (Vreugdenhil 2002) may be a solution.

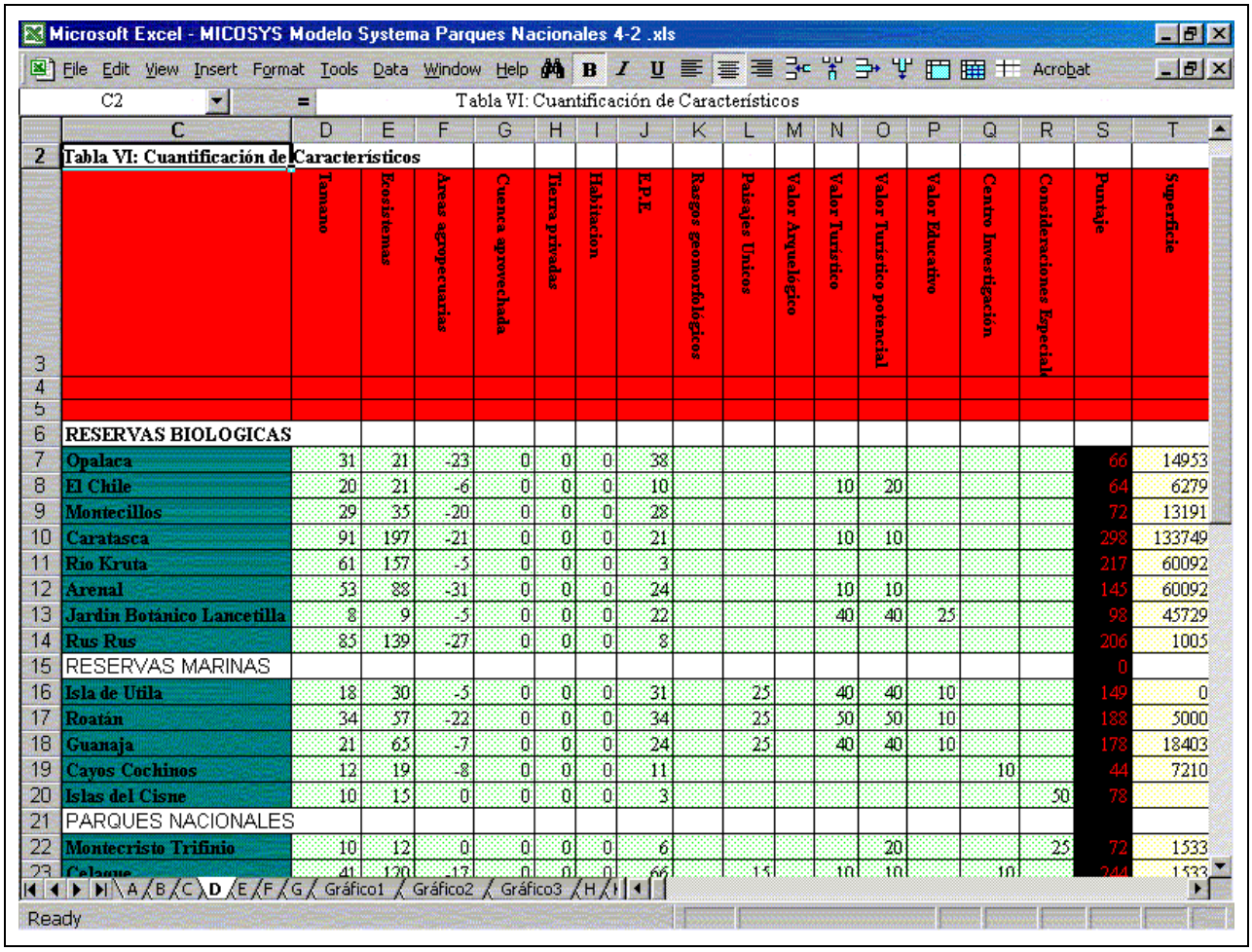
When fully composed, following the Bali World Parks Congress recommendation, the total of the protected areas system would comprise a minimum of 10 percent of the national territory, under strict biodiversity conservation legislation and management with no human occupation or land use other than non-consumptive environmental services. If less than 10% of the country is covered with natural ecosystems, one should strive for incorporating all remaining natural areas.

In the complexity of distribution of ecosystems, opportunities and challenges, there will never be one way of composing a protected areas system. In the search for a politically feasible and biologically desirable protected areas system, one may need to consider different objectives, such as varying levels of conservation security, more emphasis on diversity conservation versus the conservation of large animals, environmental services versus biodiversity conservation, etc. To deal with a variety of expectations of society it is good practice to develop different models and allow conservationists and politicians the opportunity to choose for their model of preference. It should be stressed that probably in no country in the world all the selection criteria can be met, and that each distinct model will result from choices that will have the painful consequence of sacrificing species. No model can be designed that can conserve all species of a country.

Usually, the already existing situation of a protected areas system under analysis results in some "over-representation" of some ecosystems. This tends to raise the land needs above the minimally required needs, while under- or unrepresented ecosystems still need to be added. Furthermore, some rare ecosystems that need adding are part of an area with primarily well-represented ecosystems. Usually, conservationists choose to protect such rare ecosystem embedded in the surrounding – more common - ecosystem(s), thus enhancing its security but raising the land requirements and management costs. During the final choosing of a preferred model, there may be considerable pressure to go for the maximum model. Unfortunately, there always is the chilling reality of the costs. That is why MICOSYS has been designed to automatically generate the investment and recurrent costs, thus providing the information needed to make choices deliberately through presentation of the financial consequences.

Most conservationists dislike such reality checks, and in the IUCN Best Practice Protected Area Guidelines No. 3, Kelleher (1999) concludes that “in practice, system planning has not always lived up to expectations” and advices that “such approach be complemented by a more opportunistic one, which takes advantage of favourable opportunistic circumstances”. That advice entails some serious risks. As a result of this philosophy many countries have ended up with unbalanced representation of ecosystems in protected areas systems and "on paper” such a large territory of protected areas than can be managed by the country (e.g. Vreugdenhil 1996, 1997). Later it will be argued that this may effectively jeopardise the protection of all areas of the system. Instead, when a good opportunity arises to add a new area to the protected areas system or to substitute one area for another, it should always be done through careful re-evaluation of the entire system, taking into account ecosystem representation, costs, as well as the general state of technical and financial management capacity of the country.

As mentioned previously, in the design of a protected areas system, a variety of other considerations should be taken into account as well. For that purpose one must of course incorporate as many available data as possible, like thematic and topographical maps; species databases (if available); lists and locations of species of special concern (including endemics); forestry maps; regional development plans; large-scale mega-construction projects; etc.; so that the model options may be evaluated in an appropriate broad societal context. In the desired evaluation, evaluation criteria may be added to MICOSYS, but the planning team may decide for a parallel procedure, subject to their own preferences. As mentioned previously, the IUCN Best Practice Protected Area Guidelines Series provides outstanding guidance and reference.



Microsoft Excel - MICOSYS Modelo Systema Parques Nacionales 4-2 .xls

File Edit View Insert Format Tools Data Window Help Acrobat

C2 = Tabla VI: Cuantificación de Característicos

| | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | Tabla VI: Cuantificación de Característicos | | | | | | | | | | | | | | | | | |
| 3 | | Tamano | Ecosistemas | Areas agropecuarias | Cuenca aprovechada | Tierra privadas | Habitacion | E.P.E | Rasgos geomorfológicos | Paisajes Unicos | Valor Arqueológico | Valor Turístico | Valor Turístico potencial | Valor Educativo | Centro Investigación | Consideraciones Especiales | Puntaje | Superficie |
| 4 | | | | | | | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | | | | | | | |
| 6 | RESERVAS BIOLOGICAS | | | | | | | | | | | | | | | | | |
| 7 | Opalaca | 31 | 21 | -23 | 0 | 0 | 0 | 38 | | | | | | | | | 66 | 14953 |
| 8 | El Chile | 20 | 21 | -6 | 0 | 0 | 0 | 10 | | | | 10 | 20 | | | | 64 | 6279 |
| 9 | Montecillos | 29 | 35 | -20 | 0 | 0 | 0 | 28 | | | | | | | | | 72 | 13191 |
| 10 | Caratasca | 91 | 197 | -21 | 0 | 0 | 0 | 21 | | | | 10 | 10 | | | | 298 | 133749 |
| 11 | Rio Kruta | 61 | 157 | -5 | 0 | 0 | 0 | 3 | | | | | | | | | 217 | 60092 |
| 12 | Arenal | 53 | 88 | -31 | 0 | 0 | 0 | 24 | | | | 10 | 10 | | | | 145 | 60092 |
| 13 | Jardin Botánico Lancetilla | 8 | 9 | -5 | 0 | 0 | 0 | 22 | | | | 40 | 40 | 25 | | | 98 | 45729 |
| 14 | Rus Rus | 85 | 139 | -27 | 0 | 0 | 0 | 8 | | | | | | | | | 206 | 1005 |
| 15 | RESERVAS MARINAS | | | | | | | | | | | | | | | | 0 | |
| 16 | Isla de Utila | 18 | 30 | -5 | 0 | 0 | 0 | 31 | | 25 | | 40 | 40 | 10 | | | 149 | 0 |
| 17 | Roatán | 34 | 57 | -23 | 0 | 0 | 0 | 34 | | 25 | | 50 | 50 | 10 | | | 188 | 5000 |
| 18 | Guanaja | 21 | 65 | -7 | 0 | 0 | 0 | 24 | | 25 | | 40 | 40 | 10 | | | 178 | 18403 |
| 19 | Cayos Cochinos | 12 | 19 | -8 | 0 | 0 | 0 | 11 | | | | | | | 10 | | 44 | 7210 |
| 20 | Islas del Cisne | 10 | 15 | 0 | 0 | 0 | 0 | 3 | | | | | | | | 50 | 78 | |
| 21 | PARQUES NACIONALES | | | | | | | | | | | | | | | | | |
| 22 | Montecristo Trifinio | 10 | 12 | 0 | 0 | 0 | 0 | 6 | | | | | 20 | | | 25 | 72 | 1533 |
| 23 | Celaque | 41 | 120 | 17 | 0 | 0 | 0 | 66 | | 15 | | 10 | 10 | | 10 | | 244 | 1533 |

A B C D E F G Gráfico1 Gráfico2 Gráfico3 H I

Ready

**Figure 13: Overall scoring in MICOSYS**. Scoring is based on both biological and socio-economical criteria. It is possible to customise the programme for more socio-economic parameters by adding columns for additional evaluation classes.

When all the data have been entered into MICOSYS, it will be possible to develop the conservation models. This process requires that the conservation planners guide the stakeholders through various steps of choices, and it is very important that at the highest level, the protected areas administration leadership is involved in the process so that it is fully aware of the consequences of the different choices, and in the end, fully supports the model of choice. After all, the administration's leadership will have to live with the selected model and justify it both politically and to the public.

The first step in the protected areas system composition process is the presence/gaps analysis. As the sizes of all the identified natural ecosystems of the country are entered into the programme, it evaluates the proportionate degree of conservation of each ecosystem. This will establish which ecosystem is missing or underrepresented. The system needs completion with the gaps, the ecosystems that are not found in the system. From the ecosystems map the sizes of the most promising looking parcels of missing or under-represented ecosystems are added to the spreadsheet provisionally. As this involves not-yet protected areas, their inclusion in the spreadsheet is only hypothetical and real addition to the protected areas system come after the selection of the model. Such addition requires field study and planning. The development study of conservation models does not include that and will have to limit itself to making general recommendations of where the most suitable qualifying ecosystems might be.

The next step in the process requires a systematic build-up starting from a bare "minimum conservation system". This requires a procedure of removing all non-essential areas from the spreadsheet. It is possible to go through a somewhat more automated process with a macro, but the experience is that this somewhat rustic approach gives the opportunity to take the removal decisions individually.

Criteria for removal may be varied by the conservation planning team, but it has become common practice in the application of MICOSYS to recognise three ranking levels that reflect their national significance, based on the final ranking.

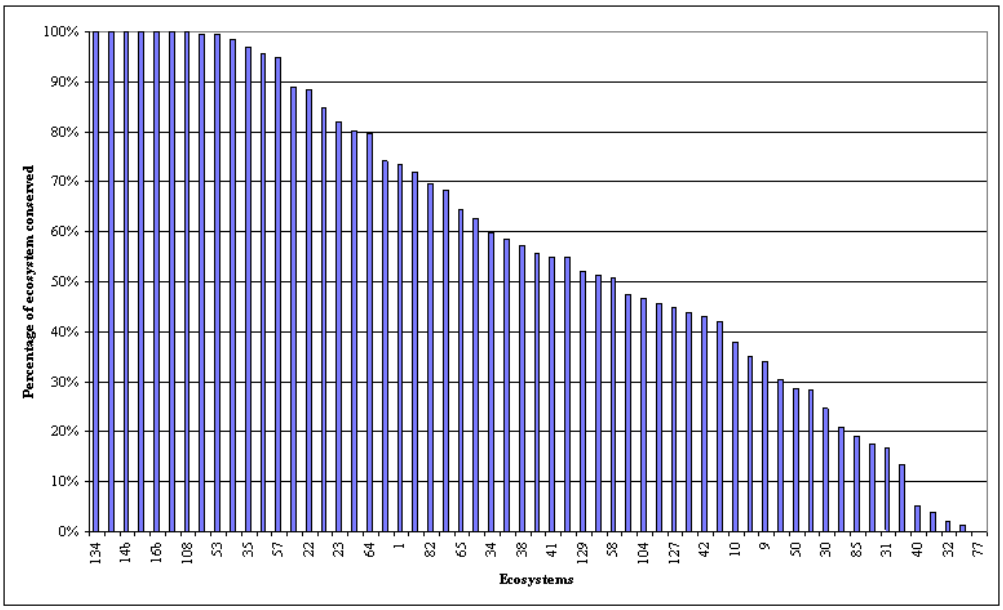



**Figure 14**: Percentage of currently remaining ecosystem preserved in the protected areas system model for Honduras. Note that only 4 are fewer than 12%. Special measures have been recommended for those ecosystems. Horizontal numbers refer to the ecosystem codes on the Map of the Ecosystems of Central America.

An area that has at least one score generated by more than 1/3 of the maximum value of anyone of the ecosystem scores, should not be taken out of the spreadsheet, as a high ecosystem score means that the area either has the largest portion of that ecosystem or that it occurs in no more than one or two other areas. Such area may be of national significance for biodiversity conservation. The reduced selection of areas has all areas, which may be of national importance, but it may still contain overrepresentation[39] of certain ecosystems, which may result in greater costs than the country can or is willing to bear.

- **Ranking level 1**: areas whose scores suggest that the areas may be of major importance for conservation of the biodiversity of the country. The scoring has been set at twice the maximum ecosystem value38. Through this scoring level all areas with significance for size or for ecosystem value are left in the spreadsheet.
- **Ranking level 2**: areas whose conservation significance to the country is not yet quite clear as they vary between levels 1 and two.
- **Ranking level 3**: areas whose scores suggest that they be of very limited relevance to the conservation in the country (areas of merely local or regional significance). The total value is less than the maximum ecosystem value. Since the composed score of ecosystem value, size socio-economic and other values are so low that there can be no nationally biological relevant features in the area, those areas should be removed from the spreadsheet.

The level 2 areas should be evaluated individually by examining from where they obtain their scores. If they come from an abundance of species of special concern, that merely reflect the fact that the area has been better studied than others, while factors like size and ecosystems score low values, the area probably is not of national significance for biodiversity conservation and is a candidate for removal from the programme. If in doubt, however, leave the area in. Once the levels are determined, the level-3 and non-essential level-2 areas may be removed from the spreadsheet by deleting the rows in Sheets A – F and the columns in Sheet G containing the relevant area information.

In practice, this procedure eliminates small areas with only commonly occurring ecosystems. After this selection procedure all remaining areas are either large or they have significant presence and/or size representation of less-common ecosystems.

A next step involves the theoretical exercise of selecting the minimum number of areas that still contain all ecosystems in the country: the bare "minimum conservation system". All large areas representing the first 5% of protected areas are kept in the system. Beyond those, all areas that only contain ecosystems that are found elsewhere in the country are removed from the spreadsheet. Even well known and well-established areas are removed if all their ecosystems are found in other areas. Of the rare ecosystems only the best example is maintained. This system is **not** compliant with the requirements of buffering against disasters and is only designed as a building block to rationally compose alternative models by adding areas in different compositions.

Even though the minimum conservation system is complete in its representation of ecosystems and species, it is highly probable that a number of ecosystems are poorly represented and highly vulnerable. To deal with this situation, the poorly represented ecosystems are analysed and areas that can substantially contribute to their viability are added to the spreadsheet to compose the most economical viable model in compliance with aforementioned selection criteria for size and risk spreading.

[38] Subject to adaptation by the planning team.

[39] "Overrepresentation" means that more is available than required for the species that for their survival depend on that particular ecosystem.

The composition of the most economical viable model does not take into account the realities of everyday. Every country has highly appreciated well-established or renowned protected areas that can never be ignored, even if their ecosystems turn out to be non-essential in the most economical viable model. Such areas can be added to the system in what may be considered the realistic or rationalised model. Other considerations may lead to differently composed models to suit a country's specific needs and ambitions. The different models must be presented with their distinct social and conservation benefits to of-set social and financial costs.

## 4.5. EFFECTIVENESS OF PROTECTED AREAS

Conservationists have tried strategies ranging from establishing and maintaining parks and other strictly protected areas (henceforth "parks") to promoting sustainable forest management and other integrated conservation and development projects. During his assignment for the World Bank in Costa Rica, Vreugdenhil (1992), at the time working for DHV-Consultants, was to "evaluate whether the existing system of national parks and biological reserves achieve their goals, namely of protecting biodiversity […] and […] Assess whether parks and reserves are being adequately protected […]" The conclusion was: "In general the Servicio de Parques Nacionales de Costa Rica has been successful in acquiring and legally protecting about 530,000 hectares - about 10% of the country's territoire - of protected reserve, with a valuable collection of ecosystems." It should be noted that Costa Rica works with an administrative concept of "Conservation Areas" regional conglomerates of reserves of all management categories. Legally, the strictly protected area classes "national park" and several categories of 'nature reserve" were still the official categories when this author checked a few years ago. The referred analysis only relates to these strictly protected areas, as at the time, areas with multiple use character, had not yet been proven to be managed sustainably. Some ecosystem representation was reported missing. Since then, some national park land has been expanded.

On the basis of aerial surveys, the statement of the SPN that no legal inhabitants live in the areas could be reconfirmed. Field trips showed fine wildlife visibility and many tracks, all indications that anti-poaching protection was functional for the survival of many conspicuous species. In general, effective protection of protected areas in Costa Rica may be considered adequate." It was also assessed that the SPN had 404 staff members, about three quarters of which were rangers, or about 1 per 2,000 ha. Panamá had the second highest staff density in Central America with 192 staff members for about 1.8 million ha[40] (Vreugdenhil 1997), half of which were rangers, amounting to about 1 ranger per 20,000 ha. Thanks to, at the time, rather recent staff build-up, the impression existed that illegal settlement in protected areas had slowed down considerably (pers. com by several parks directors). Countries with such low numbers of staff as 50 – 60 employees, like Honduras and Nicaragua (Vreugdenhil 1996, Cedeño and Vreugdenhil 1996), were still struggling with continuing illegal settlements. Honduras has since considerably increased its protected areas staff, to currently 220 (V.L. Archaga pers. com.) and further invasions and ecosystem transformation appears to have slowed down considerably in the protected areas with field staff.

Bruner et al. (2001) published a study on how well strictly protected area, which he refers to as "parks", measure up among these alternatives and analysed the main factors of their success. The study selected 93 representative parks out of a pre-examined group of 535 parks. The study is so important in this context that an extended summary of the publication has been excerpted from Bruner et al., copyright 2001, American Association for the Advancement of Science. With regard to this excerpt the term "park" will be used in deviation of the terminology "protected area" used in our document.

"Critics claim that in the context of growing human pressures and development needs, parks cannot protect the biological resources within their borders, and there is a widespread sense that parks are simply not working. The accuracy of these claims is of critical importance to policy and funding decisions. If parks are failing despite best efforts, then better options should be sought. If, on the other hand, parks are performing relatively well in a context of serious threats and limited resources, or are simply performing better than the alternatives, their level of support should be increased. […]

Eighty-three percent of parks were fully holding their borders against agricultural encroachment. Only 17% of the parks experienced more clearing than natural regeneration since establishment. This is a substantial achievement, given that the median age of the parks in the sample was 23 years. […]

To test effectiveness over a wider range of threats, we compared anthropogenic impacts in the 10-km belt surrounding parks with the level of impacts within park boundaries for five different threats (Fig. 2). This comparison shows that the parks in our sample are under great pressure from clearing, hunting, and logging, and to a lesser extent, fire and grazing. A comparison of the conditions inside the parks with the surrounding area shows that for all five threats, parks were in significantly better condition than their surrounding areas. Because we used relatively few response categories to represent the entire range of outcomes (e.g., four categories were used to classify the abundance of game animals, ranging from pristine levels of abundance to absent), any differences found between the parks and their surroundings are great.

[40] This territory comprised all management categories.

**Figure 15**: Change in the area of natural vegetation since establishment for 86 tropical parks. The majority of parks have either experienced no net clearing or have actually increased natural vegetative cover. Median park age is 23 years.

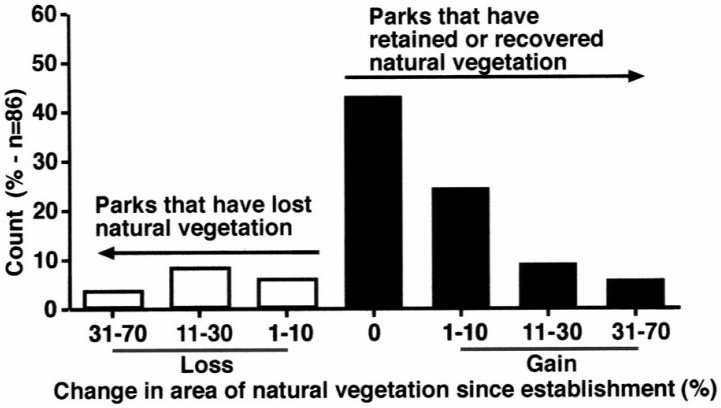



**Table 9**: Park effectiveness against anthropogenic threats. Shown for each threat is the percentage of parks surveyed that are either in better condition (functioning) than the surrounding 10-km belt or in equal or worse condition (not functioning). Also shown is the percentage of parks with no presence of each threat in the surrounding area (untested parks).

| Type of impact | n | Functioning (% of tested parks) | Not functioning (% of tested parks) | Untested parks (% of total) |
|---|---|---|---|---|
| **Clearing** | 85 | 97.2 | 2.8 | 16.5 |
| **Logging** | 84 | 85.2 | 14.8 | 3.6 |
| **Fire** | 87 | 81.0 | 19.0 | 27.6 |
| **Hunting** | 91 | 62.2 | 37.8 | 1.1 |
| **Grazing** | 88 | 59.7 | 40.3 | 12.5 |

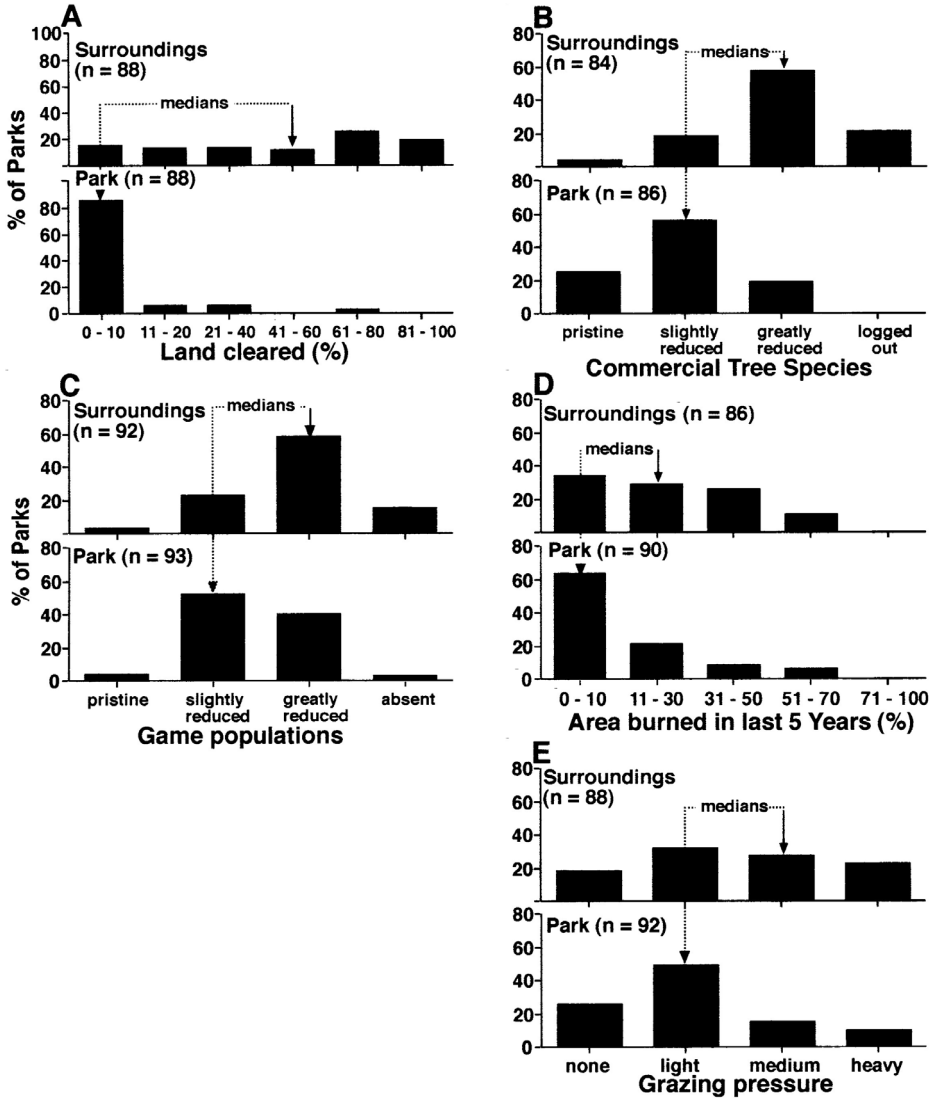
Parks are more effective at mitigating some impacts than others. Parks are in far better condition than their surroundings with respect to land clearing, with the majority of parks being intact or only slightly cleared. Parks were more heavily impacted by logging and hunting, but these impacts were still reduced considerably compared with their surroundings. Finally, although parks were still in significantly better condition than their surroundings with respect to damage from fire and grazing, the differences were less pronounced.

More than 80% of the individual parks were in better condition than their surroundings for clearing, logging, and fire, including 97% for clearing. About 60% of the parks were in better condition than land outside their borders with respect to hunting and grazing. We also investigated which management activities and local conditions correlated with effectiveness, which we defined as the difference between illegal impacts inside the park and the surrounding 10-km belt. [...]

Park effectiveness correlated most strongly with density of guards (Table 2). The median density of guards in the 15 most effective parks was more than eight times higher than in the 15 least effective parks (3 guards per 100 km2 in the 15 most effective parks compared with 0.4 guards per 100 km2 in the least effective). However, enforcement capacity (a composite variable of training, equipment, and salary) was not found to correlate with effectiveness, suggesting that these characteristics are less important than the presence of guards. Effectiveness was also significantly correlated with the level of deterrents to illegal activities in the park.

Deterrents were measured as the product of the probability of apprehending violators when guards detected a violation (either in progress or after-the-fact) by the probability of the violator receiving a significant sanction if apprehended. Deterrents against clearing and logging correlated with park effectiveness, whereas deterrents against hunting did not. The degree of border demarcation and the existence of direct compensation programs to local communities (Table 2) were also found to correlate significantly with management effectiveness. Other factors potentially related to park success did not correlate significantly with effectiveness, including number of people living in the park, accessibility, local support, percentage of the park area contested, budget, number of staff working on economic development or education, and local involvement of communities in park management. The findings of this study suggest three basic conclusions. First, the claim that the majority of parks in tropical countries are paper parks i.e., parks in name only is not substantiated. Tropical parks have been surprisingly effective at protecting the ecosystems and species within their borders in the context of chronic underfunding and significant land-use pressure. They have been especially effective in preventing land clearing, arguably the most serious threat to biodiversity. Second, despite their successes, there is a clear need to increase support for parks to improve effectiveness against all threats, perhaps especially against hunting. Finally, these findings suggest that parks should remain a central component of conservation strategies. Both creating new parks and addressing the tractable problem of making existing parks perform better will make a significant contribution to long-term biodiversity conservation in the tropics."

**Figure 16: Effectiveness of parks for five human factors destructive to biodiversity**; **Comparison of the condition of parks to the surrounding 10-km belt**. For all five anthropogenic impacts, parks were in significantly better condition than their surrounding areas (Mann-Whitney U-test) (A) Clearing: P 5 0.000; (B) logging: P 5 0.000; (C) hunting: P 5 0.000; (D) fire: P 5 0.000; and (E) grazing: P 5 0.006.




Vreugdenhil's many years of reviews of personnel data combined with field observations in Central America, strongly corroborate the findings of Bruner. However, where Bruner et al. (2001) end their conclusions, this document adds another observation after a dialogue with A.G. Bruner (pers. com.): The territorial expansion of a protected areas system will lead to the need of additional personnel. If expansion takes place without assigning staff to a new area commensurate to the level of threat it faces, the area will not effectively be protected, which can not only result in the continuation of ecosystem alteration, but also in disrespect for the conservation legislation; this may result in disrespect in other areas as well. If personnel does get assigned to the added area without an increase of the staff of the system as a whole, the area increase will lead to dilution of ranger density in the areas from where the staff for the new area was taken, and thereby the land addition raises the level of threat to biodiversity conservation elsewhere. In general, when field staff of a protected areas system is under the required minimum density, the assignation of new territory to the existing protected areas system should be carried out with great caution after careful justification of the need for such expansion.

This principle holds true also for biological corridors. Biological corridors that require the input of protected areas staff in situations where protected areas systems are below their minimum field staff requirements absorb staffing input from the existing protected areas, thus shifting the level of protection from the areas that are most essential to effective biodiversity conservation to those that are primarily complementary. The effect of a net reduction of staff density resulting from the creation of biological corridors has essentially been overlooked or left unmentioned by many who promote their creation (e.g. see Foppen et al. 2000, CCAD 1998).

## 4.6. COMPLEMENTARY MEASURES

Protected areas are not the only conservation tool, particularly so in countries with predominantly cultural landscapes such in much of Northern and parts of central Eurasia, where – due to highly fragmented conditions protected areas alone will not be sufficient to conserve biodiversity in the long term (Janzen 1983). For some species, such as dispersed species at low densities across large areas, conservation of the landscape beyond protected areas through general regulatory legislation and incentives will be necessary (Bennun & Eken 2003). However, in countries where natural areas still wait to be evaluated and selected to protected areas systems, the completion of the protected areas systems should enjoy priority, both in financing and policy development. After all, it is always possible to improve legislation, but it is very difficult, slow and usually extremely costly to revert human land-use to previous conditions.

### Indemnity fund

A small indemnity fund may be created to compensate for damages caused by rare animals leaving protected areas, such as large predators. Compensation should be applied with restraint and only after negotiating an

agreement with local communities to forgo hunting threatened animals outside a reserve. Strict rules of use must be set and claims must be carefully verified to prevent the fund from becoming abused as a source of subsidy.

**BOX 14: EXAMPLE OF A COMPENSATION FUND**

"Through The Bailey Wildlife Foundation Grizzly Bear Compensation Trust, if a landowner suspects that a grizzly has killed livestock, he or she should cover the remains with a tarp, to protect the remains, and immediately call state or federal officials (http://www.defenders.org/wildlife/grizzly/grizcomp.html 2003). The trustees, 'Defenders' rely on those officials, tribal biologists or animal damage control experts to examine suspected losses and confirm or deny the claims. If agency officials verify that a grizzly bear killed the livestock, an agency representative fills out a report and sends it to Defenders of Wildlife. There is no paperwork for the rancher.

Defenders then contacts the producer and asks for his or her assessment of the livestock's value. That figure is compared with current auction reports and livestock prices as reported in local newspapers. A check is then sent to the producer to compensate for the loss."

**Threatened Species Management Fund**

Occasionally, certain species need special management measures. A small fund should be available for such purposes, but only a fraction of the management costs may be dedicated for this purpose, as funds spent on this purpose will be in competition with the funds spent on general protected areas management, and thus, with all the other species that need protection – among which are many other rare and endemic species.

***Ex situ* live collections**

Botanical gardens can be valuable tools for academic botanical and lower level environmental education. Universities should be stimulated to set up collections of the nationally endemic and restricted-distribution species. For maximum educational benefit and income generating possibilities is should – climate permitting - be located near a big city; countries with strongly distinct climatic conditions may need more locations.

Particularly amphibians are reported to suffer serious declines and ex situ backup populations may be set up at low costs in combination with a botanical garden. In general, the costs of keeping a live-collection of herpetofauna is relatively low, while a herpetofauna house may raise the attractiveness of a botanical garden for both tourists and children. It may therefore, be considered to establish a collection of at least the most threatened and the most spectacular species of the country in a botanical garden. Incentive subsidies may be provided from the threatened species management fund to promote "backup" *ex-situ* conservation functionality, but the main funding must come from non-protected areas funding and entry fees.

## 4.7.COST APROXIMATION

### 4.7.1. Cost-efficiency in conservation programming

The creation of a protected areas system requires that a financing mechanism be created for establishing the system, making it functional and maintaining it. Much has been written about the economic values of biodiversity and protected areas (de Groot 1992, Barbier, et. al. 1997, Pearce and Moran 1994) creating financing mechanisms, (e.g. Munasinghe and McNeely 1994) and actual amount spent, (James et al. 1999), but very little has been found on what the costs involve of creating a protected areas system and maintaining it. Motivated by experiences in government financing, Vreugdenhil (1992) incorporated a costs approximation module in MICOSYS. Often, area managers will present their requests for (more) financing to their organisational superiors or external financers (donors) without being able to place their needs in the context of the system as a whole. An integral protected areas budget hierarchy could be structured as follows: reserve/protected-area-system/budget-Ministry-of-Agriculture/national-budget. If financiers don't have a perspective of the relative importance of the areas, their primary tasks, cost factors and actual costs, they are ill-equipped to maximise the benefits of their financial resources. MICOSYS calculates costs estimates for planning and budgeting purposes by building them up proportionately to the size of each area for specific cost factors like equipment, buildings, staff, etc.

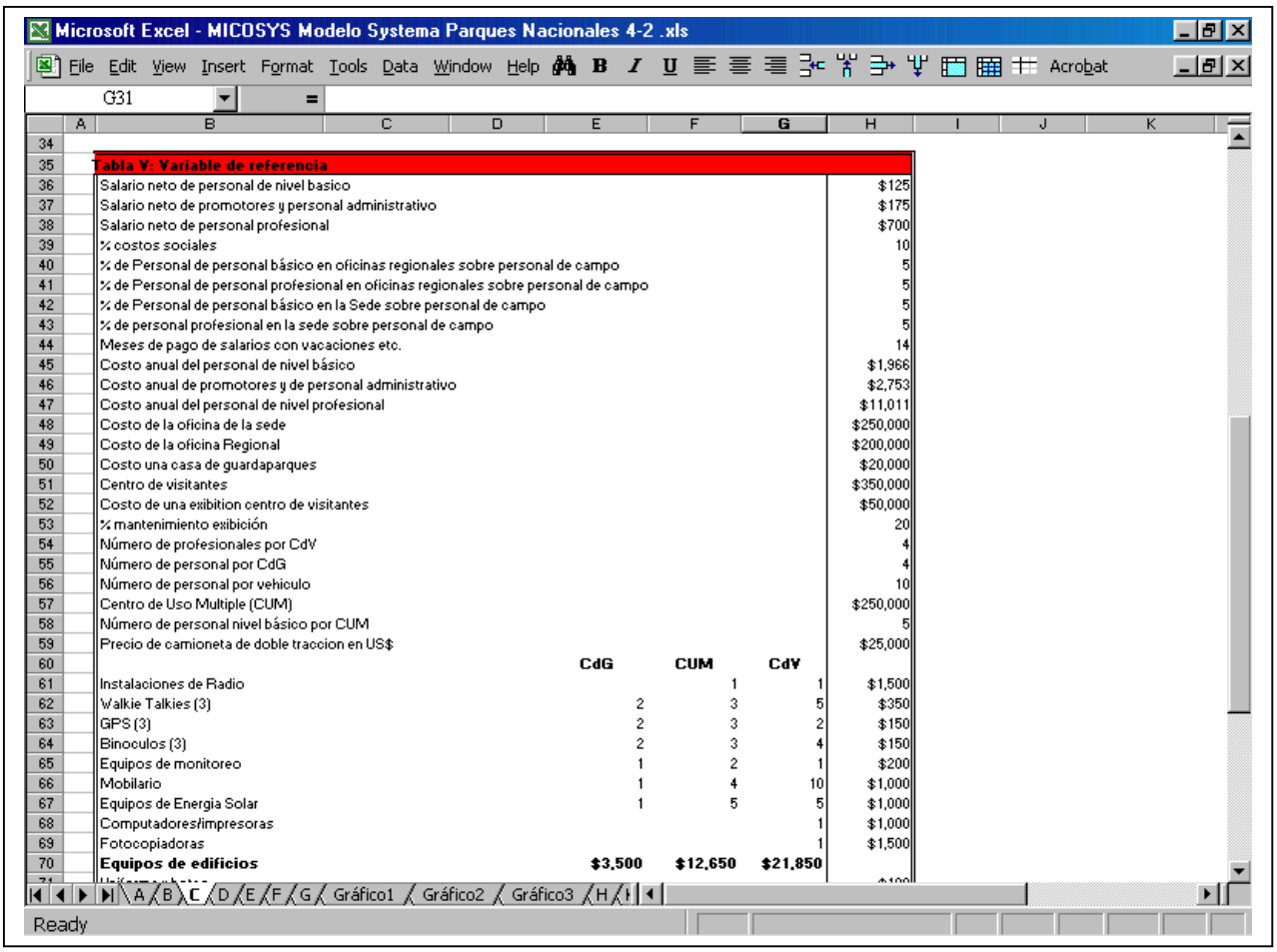
**Low natural resources management requirements in natural ecosystems**

The financial estimates in MICOSYS have been designed on the assumption that management of protected areas should first and for all focus on the continuity of the resource, assuming a narrow management task. Most of the protected areas of national or global significance in developing countries primarily comprise natural ecosystems, or extensively used grazing lands. The management should primarily focus on prevention and mitigation of undesirable external effects - like fires, habitat conversion or theft of wood and poaching –and the facilitation of the wise use of the resource – like visitation, out-doors environmental education, research, the harvesting of water or grazing; of all those activities visitation usually requires the most attention.

### 4.7.2. Some cost factors

This chapter provides some specific cost calculations in MICOSYS, assuming a narrow management mandate[41]. In order to be as realistic as possible, the specific case of Honduras is presented. Table V is a reference table for cost factors and constants for logarithms. As MICOSYS for Honduras is programmed in Spanish, each factor in this chapter will be presented bilingually.

[41] Excluded costs for extension services and promotion of environmentally friendly land-use and income-generating environmental services to neighbouring communities.



Microsoft Excel - MICOSYS Modelo Systema Parques Nacionales 4-2 .xls

| | | |
|---|---|---|
| **Tabla V: Variable de referencia** | | |
| Salario neto de personal de nivel basico | | $125 |
| Salario neto de promotores y personal administrativo | | $175 |
| Salario neto de personal profesional | | $700 |
| % costos sociales | | 10 |
| % de Personal de personal básico en oficinas regionales sobre personal de campo | | 5 |
| % de Personal de personal profesional en oficinas regionales sobre personal de campo | | 5 |
| % de Personal de personal básico en la Sede sobre personal de campo | | 5 |
| % de personal profesional en la sede sobre personal de campo | | 5 |
| Meses de pago de salarios con vacaciones etc. | | 14 |
| Costo anual del personal de nivel básico | | $1,966 |
| Costo anual de promotores y de personal administrativo | | $2,753 |
| Costo anual del personal de nivel profesional | | $11,011 |
| Costo de la oficina de la sede | | $250,000 |
| Costo de la oficina Regional | | $200,000 |
| Costo una casa de guardaparques | | $20,000 |
| Centro de visitantes | | $350,000 |
| Costo de una exibition centro de visitantes | | $50,000 |
| % mantenimiento exibición | | 20 |
| Número de profesionales por CdV | | 4 |
| Número de personal por CdG | | 4 |
| Número de personal por vehiculo | | 10 |
| Centro de Uso Multiple (CUM) | | $250,000 |
| Número de personal nivel básico por CUM | | 5 |
| Precio de camioneta de doble traccion en US$ | | $25,000 |

| | CdG | CUM | CdV | |
|---|---|---|---|---|
| Instalaciones de Radio | | 1 | 1 | $1,500 |
| Walkie Talkies (3) | 2 | 3 | 5 | $350 |
| GPS (3) | 2 | 3 | 2 | $150 |
| Binoculos (3) | 2 | 3 | 4 | $150 |
| Equipos de monitoreo | 1 | 2 | 1 | $200 |
| Mobilario | 1 | 4 | 10 | $1,000 |
| Equipos de Energia Solar | 1 | 5 | 5 | $1,000 |
| Computadores/impresoras | | | 1 | $1,000 |
| Fotocopiadoras | | | 1 | $1,500 |
| **Equipos de edificios** | **$3,500** | **$12,650** | **$21,850** | |

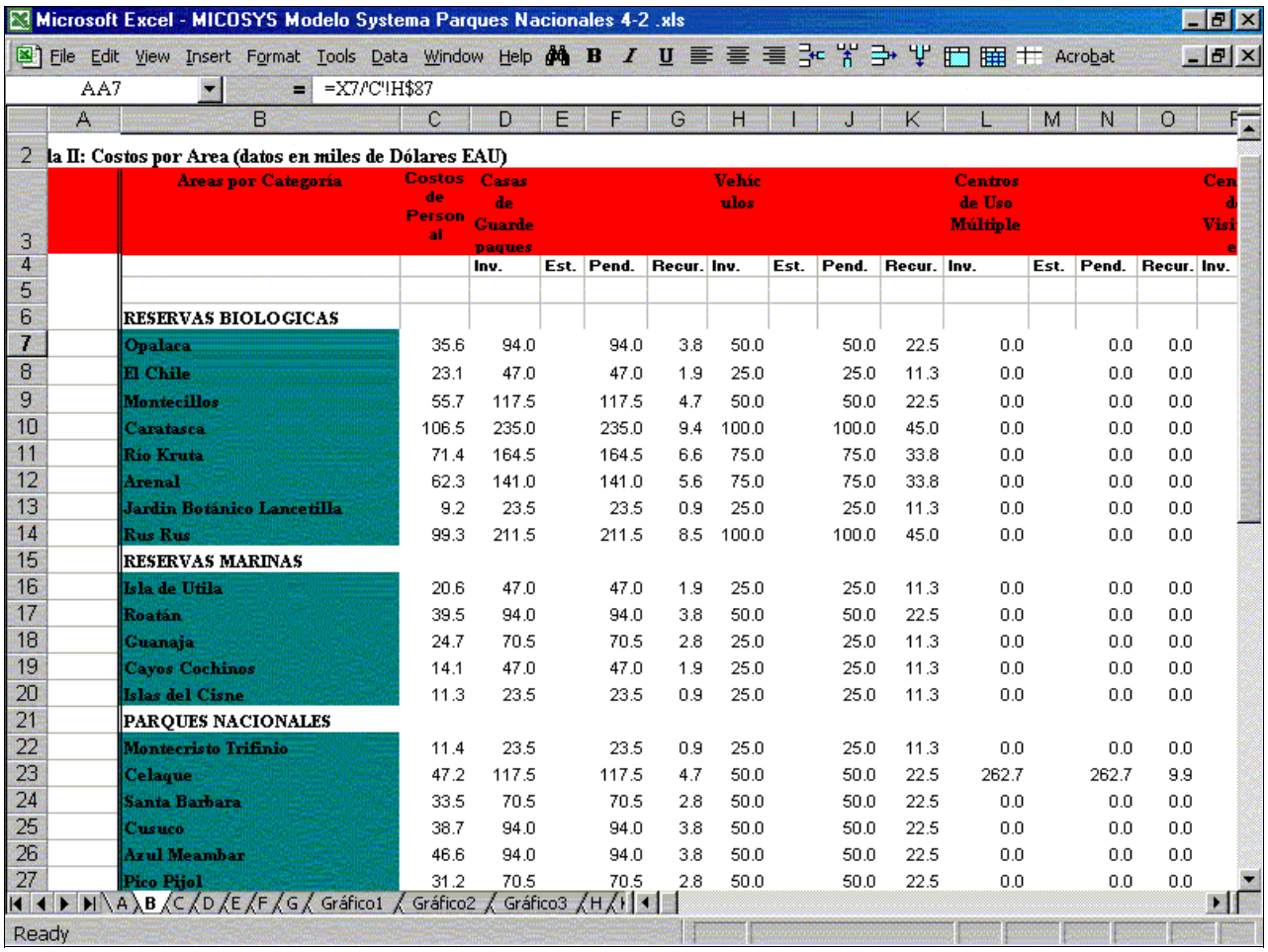
**Figure 17**: Table of constants to customize MICOSYS to a country's needs

The cost factors can be found in its tables Sheet B, Table II, Sheet C, Tables III and IV of the spreadsheet. **Sheet B, Table II, Costs per Area / Costos por Area**[42] calculates the costs per area. According to the characteristics, the cost category may have a column for investment costs and recurrent costs. In the case of investment costs, another column is shown in which the realised/establecido units are entered, which in turn calculates pending costs/costos pendientes by deducting realised units from the required units in Sheet A, Table I. This table may be used by administrators to see how far they have advance in their investment needs.

Yearly returning operational or Recurrent costs / costos recurridos over equipment and infrastructure are calculated over the total investment costs on the basis of the factors write-off / amortigación and maintenance / mantenimiento as a percentages of the investment costs. In the entire table, only realised units are entered manually. All other columns are calculated automatically and should not be touched. Some of the principal factors presented:

**`Staffing costs / Costos de Personal`**
Costs are based on the number of required staff for each area, referenced from Table I. Administrative staff for the regional offices is a bit more expensive than for rangers, but as the numbers are low, this will not lead to major differences in the total staffing costs.

[42] Bilingual terms are used because the MICOSYS version for Honduras is in Spanish.



Microsoft Excel - MICOSYS Modelo Systema Parques Nacionales 4-2 .xls

File Edit View Insert Format Tools Data Window Help Acrobat

AA7 = =X7/'C'!H$87

la II: Costos por Area (datos en miles de Dólares EAU)

| Areas por Categoria | Costos de Personal | Casas de Guardeparques | | | Vehículos | | | Centros de Uso Múltiple | | | Centros de Visite | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Inv. | Est. | Pend. | Recur. | Inv. | Est. | Pend. | Recur. | Inv. | Est. | Pend. | Recur. | Inv. |
| RESERVAS BIOLOGICAS | | | | | | | | | | | | | | |
| Opalaca | 35.6 | 94.0 | | 94.0 | 3.8 | 50.0 | | 50.0 | 22.5 | 0.0 | | 0.0 | 0.0 | |
| El Chile | 23.1 | 47.0 | | 47.0 | 1.9 | 25.0 | | 25.0 | 11.3 | 0.0 | | 0.0 | 0.0 | |
| Montecillos | 55.7 | 117.5 | | 117.5 | 4.7 | 50.0 | | 50.0 | 22.5 | 0.0 | | 0.0 | 0.0 | |
| Caratasca | 106.5 | 235.0 | | 235.0 | 9.4 | 100.0 | | 100.0 | 45.0 | 0.0 | | 0.0 | 0.0 | |
| Rio Kruta | 71.4 | 164.5 | | 164.5 | 6.6 | 75.0 | | 75.0 | 33.8 | 0.0 | | 0.0 | 0.0 | |
| Arenal | 62.3 | 141.0 | | 141.0 | 5.6 | 75.0 | | 75.0 | 33.8 | 0.0 | | 0.0 | 0.0 | |
| Jardin Botánico Lancetilla | 9.2 | 23.5 | | 23.5 | 0.9 | 25.0 | | 25.0 | 11.3 | 0.0 | | 0.0 | 0.0 | |
| Rus Rus | 99.3 | 211.5 | | 211.5 | 8.5 | 100.0 | | 100.0 | 45.0 | 0.0 | | 0.0 | 0.0 | |
| RESERVAS MARINAS | | | | | | | | | | | | | | |
| Isla de Utila | 20.6 | 47.0 | | 47.0 | 1.9 | 25.0 | | 25.0 | 11.3 | 0.0 | | 0.0 | 0.0 | |
| Roatán | 39.5 | 94.0 | | 94.0 | 3.8 | 50.0 | | 50.0 | 22.5 | 0.0 | | 0.0 | 0.0 | |
| Guanaja | 24.7 | 70.5 | | 70.5 | 2.8 | 25.0 | | 25.0 | 11.3 | 0.0 | | 0.0 | 0.0 | |
| Cayos Cochinos | 14.1 | 47.0 | | 47.0 | 1.9 | 25.0 | | 25.0 | 11.3 | 0.0 | | 0.0 | 0.0 | |
| Islas del Cisne | 11.3 | 23.5 | | 23.5 | 0.9 | 25.0 | | 25.0 | 11.3 | 0.0 | | 0.0 | 0.0 | |
| PARQUES NACIONALES | | | | | | | | | | | | | | |
| Montecristo Trifinio | 11.4 | 23.5 | | 23.5 | 0.9 | 25.0 | | 25.0 | 11.3 | 0.0 | | 0.0 | 0.0 | |
| Celaque | 47.2 | 117.5 | | 117.5 | 4.7 | 50.0 | | 50.0 | 22.5 | 262.7 | | 262.7 | 9.9 | |
| Santa Barbara | 33.5 | 70.5 | | 70.5 | 2.8 | 50.0 | | 50.0 | 22.5 | 0.0 | | 0.0 | 0.0 | |
| Cusuco | 38.7 | 94.0 | | 94.0 | 3.8 | 50.0 | | 50.0 | 22.5 | 0.0 | | 0.0 | 0.0 | |
| Azul Meambar | 46.6 | 94.0 | | 94.0 | 3.8 | 50.0 | | 50.0 | 22.5 | 0.0 | | 0.0 | 0.0 | |
| Pico Pijol | 31.2 | 70.5 | | 70.5 | 2.8 | 50.0 | | 50.0 | 22.5 | 0.0 | | 0.0 | 0.0 | |

A B C D E F G Gráfico1 Gráfico2 Gráfico3 H I

Ready

**Figure 18**: Cost estimates per protected area. For each area distinction is made for investment needs and how much has already been materialised as well as recurrent costs.

**Ranger stations / Casas de Guardeparques**

The investment costs of ranger stations is referenced from Table V. Costs are calculated with standard equipment costs, solar energy units, including GPS, portable radios, binoculars, an amount for monitoring equipment, basic furniture (beds, table, chairs, kitchen gear, etc.). Equipment write-off and maintenance is included in the relevant factors of the buildings. The same principle applies for the other types of buildings.

**Vehicles / Vehiculos**

The investment costs of vehicles is referenced from Table V. Recurrent costs consist of write off, maintenance and fuel.

**Multiple Use Centres / Centros de Uso Múltiple**

The investment costs of Multiple Use Centres is referenced from Table V. Costs are calculated with standard equipment costs, including a fixed radio, solar energy units, GPS, walkie talkies, binoculars, an amount for monitoring equipment and basic furniture (basic furniture, kitchen gear, etc.). The total is summed up in Table V and may be changed according to need.

**Visitor Centres / Centros de Visitantes**

Visitor centres are the “business cards” of a protected areas system and are very effective for communication with visitors (Eagles 2002). It is better to only have a few high profile, well-designed and well-operated ones on key locations than a poor-looking structure in every area. Good quality infrastructure in the touristically most attractive protected areas allows the administration to charge considerable entry fees. As a rule of thumb, a good visitor centre with a high quality exhibition should cost about US $500,000. Costs are calculated in the same fashion as for multiple use centres.

Area-specific-education/interpretation is a task, which involves the education of the direct users of the areas, in casu the visitors, and the directly affected population. Promotion of goodwill and appreciation of the on-site conservation program require intensive involvement of the management staff at all levels as well as full-time educational staff as interfaces between management staff and the public. Area specific education not only helps the public appreciate the values of the area, but it also justifies the existence of an area and its management. The task requires specific area related knowledge on the resource and its management. In theory, the task could be contracted out or delegated, by doing so the area administration would forgo an opportunity to relate with the public, and it would restrict its task to primarily law-enforcement and monitoring, which would be experienced as respectively negative or mainly go unseen by the general public.

**BOX 15: SOME CASES OF MONITORING COSTS**

For the Netherlands, water management is essential for the physical continuation of 50% of the national territory. In 1987, Rijkswaterstaat, the Dutch equivalent of the US Corps of Engineers, contracted an accountant study to analyse how much of its budget and personnel was spent and should be spent on M&E of the Dutch system of National Waters. It was assessed that annually, the equivalent of about 1987 Euro 53 million was spent on - both physical and environmental - monitoring in national waters (excluding considerable monitoring by provincial institutions and Water Boards). During a discussion at management level it was assessed that no more than 5 - 10% of the budget for water management (including personnel costs) should be spent on monitoring; The study showed that Rijkswaterstaat spent closer to 5% and expenditure on monitoring was well within its range of need. This example is given as it reflects one of the few cases of solidly institutionalised monitoring in the world – with some series dating back for centuries – of which all the costs are known in detail.

With National Parks Service (of the USA) budget-analyst K. Mueller (pers. com.), a very coarse approximation was made on the percentile expenditure on monitoring and contract research of the NPS. Of the regular 2002 NPS budget of US $2.3 billion plus an additional US $500 million on external funding for the national parks (inter alia road funds comes from a different budget), two/third or US $1.9 billion is spent on natural heritage and US $900 million on cultural heritage. A further analysis of the budget sub-activity "Resource Stewardship" indicates that about US $39 million[43] is spent on management related research and monitoring, bringing the total percentage of management related research and monitoring of natural resources at about 2% of the annual budget for natural heritage conservation by the USA National Parks Service. This percentage does not include the costs of park staff[44] time budget. The real percentage is probably somewhat higher. The purpose of this example, however, is not to accurately assess the expenditure by the NPS, but to give an indication of the order of magnitude spent by one of the most advanced protected areas systems in the world.

[43] Natural Resources Research support $9.3 million, Everglades Restoration and Research, US $10.9, Vital signs monitoring $8.4 million, accelerated inventories $7.3 million, assess watershed conditions, $3.1 million.

[44] E.g. monitoring activities include registration of infractions of the law performed by ranges staff and the sales of entry tickets, which provides the NPS with valuable information on visitation intensity.

Such would be a strategic public-relations disadvantage, and MICOSYS incorporates area-specific education/interpretation as a primary task of a protected areas system. All other tasks, such as transportation, tour-operating, general ecological research are considered non-essential tasks and are not included in the budget calculation of the programme.

**Trails/ Senderos**

The costs of trails are estimated on the assumption that they are built with local materials, mainly involving labour for construction. Occasionally, simple stairs must be built or muddy or swampy sections must be bridged with shelves or steps. For such conditions, wood is assumed as construction material. A cubic meter factor per kilometre (see Vreugdenhil 1992) is given in Table V, as well as a percentage for maintenance.

When using rangers in the a monitoring programme, the effective contribution to monitoring is much higher: Assuming equivalence for monitoring, visitor service and law-enforcement[45] in the tasks of the rangers, the budget spent on monitoring would be about 20% (including the salary for the monitoring coordinator). Given the high percentage of costs of field staff (rangers), the specific budget costs of research and monitoring are kept at only 2% of the total budget that should be spent on monitoring equipment, brief studies on highly threatened species and for invading species, monitoring collaboration programmes with universities, periodic change detection analyses and reconnaissance flights.

In principle, all the tasks may be delegated or contracted out to other levels of government or the private sector, commercial or non-profit. However conservation promotion, basic field-monitoring and protection are so essential to a protected areas system, that the system should never become fully dependent on external institutions for law enforcement (Vreugdenhil 1996), although collaboration with police and – where appropriate the military – could considerably reinforce the system (MacKinnon et al. 1986), which could result in lower staff density requirements in the field. Integrated conservation promotion, basic field-monitoring and law-enforcement being primary tasks, should be included in protected areas cost assessments. As argued previously, these tasks are highly interrelated and usually they are carried out by the same staff. It is therefore difficult to disentangle monitoring from the law-enforcement task.

Other interventions, such as general biological research in protected areas and generic environmental education should be carried under a ministry of education, respectively by the universities for the advancement of science and by different levels of schools for reaching the entire community of children of all ages. Such tasks

[45] Salaries of rangers, ranger stations and transportation amount to about 50 - 60%.

cannot be budgeted under a protected areas administration.

**Threatened Species Management Fund / Fondo de manejo de especies amenazadas**
A percentage can be set to dedicate funds for management of threatened species; usually no more than one percent.

### Box 16: US National Parks Service expenditure on restoration

The USA National Parks Service (2002 and Mueller, pers. com.), spends about 7% of the national parks budget dedicated to the conservation of its natural heritage on active natural resources restoration[46]. It should be noted, however, that in its more than 130 years of existence, the NPS has entered in a phase of fine-tuning, where it has started to spend on restoration programmes (e.g. the restoration of the Everglades). Resources management in newly created protected areas systems would probably be more effectively spent on protecting what is still in tact then on restoring what is already lost, by focussing on
establishment issues, like demarcation, management planning, patrolling and basic monitoring. One should bear in mind that it is far more expensive to restore nature than it is to conserve intact nature and it would not make sense to spend proportionately large part of the budget if the conservation targets of intact ecosystems cannot be met. Therefore, the programme only proposes a species management fund, which as a default would receive 2% of the national annual budget for *in situ* conservation. This would primarily be dedicated to species of special concern that cannot be incorporated in the protected areas system.

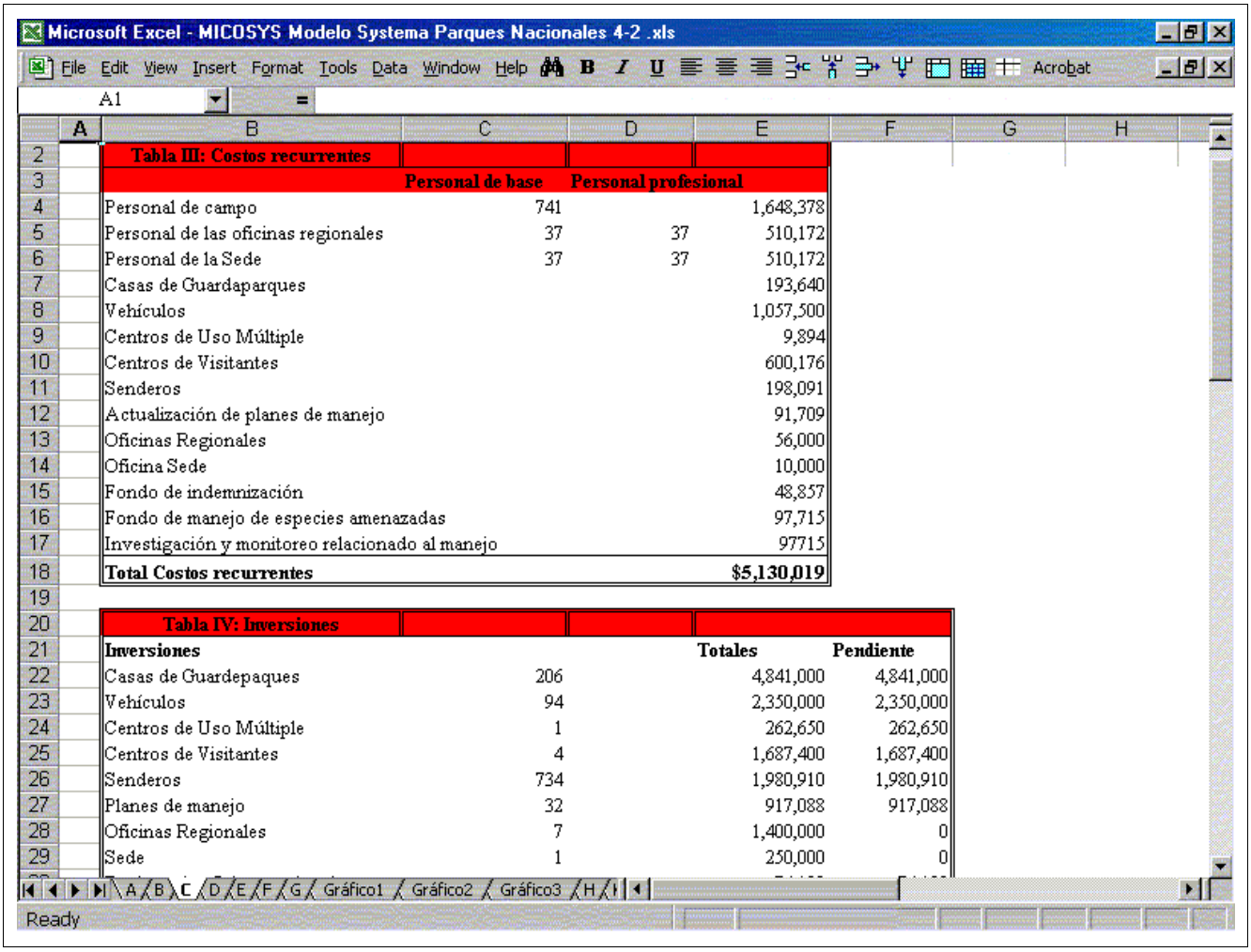
**Marketing / Mercadeo**
One of the greatest problems of protected areas in developing countries is not excessive visitation pressure, but rather the opposite, a lack of visitation. Without visitation, protected areas risk losing public interest and pressure rises to make alternative use of them, particularly converting land for agro-productive purposes. Also, visitation is one of the few direct sources available for generating income for management purposes. To raise visitation, protected areas administrations need to market. Important marketing media are internet and advertisements in nature magazines in the USA, Europe, Japan and Australia. A percentage can be set over total management costs, usually no more than one percent.

Headquarters and Regional Offices / Sede and Oficinas regionales
The distribution of headquarters and regional offices must be determined on geographical-administrative considerations. They should be budgeted typically as cost-effective stand-alone buildings at market prices. They may be existing residential buildings or a floor of an office building. An investment amount is entered, but the actual financing mechanism may be based on renting, rather than purchasing.

**Value of private lands / Propiedad privado**
On Sheet A, Table I the monetary values of privately owned land are calculated on the basis of a nationwide average, using the reference in Sheet C, Table V: Basic Data. The column calculates automatically, but the calculation may be adapted for individual areas by replacing the cell reference by a region specific value or by entering the total land value in the cell if known. These costs should enter in Sheet C, Table IV, Investments / Inversiones. If the information is not available it is probably better to leave this category out and make a text comment to report this in the final report.

In most developing countries, this situation is completely ignored by international financing organisations as well as protected areas administrations. Ignored private ownership forms a serious threat to conservation efforts, and ultimately they land-owners probably shall have to be compensated for the value of their lands.

[46] The budget is $153 million minus about $19 million for monitoring and research activities within this budget.



Microsoft Excel - MICOSYS Modelo Systema Parques Nacionales 4-2 .xls

| Tabla III: Costos recurrentes | | | |
|---|---|---|---|
| | Personal de base | Personal profesional | |
| Personal de campo | 741 | | 1,648,378 |
| Personal de las oficinas regionales | 37 | 37 | 510,172 |
| Personal de la Sede | 37 | 37 | 510,172 |
| Casas de Guardaparques | | | 193,640 |
| Vehículos | | | 1,057,500 |
| Centros de Uso Múltiple | | | 9,894 |
| Centros de Visitantes | | | 600,176 |
| Senderos | | | 198,091 |
| Actualización de planes de manejo | | | 91,709 |
| Oficinas Regionales | | | 56,000 |
| Oficina Sede | | | 10,000 |
| Fondo de indemnización | | | 48,857 |
| Fondo de manejo de especies amenazadas | | | 97,715 |
| Investigación y monitoreo relacionado al manejo | | | 97715 |
| **Total Costos recurrentes** | | | **$5,130,019** |

| Tabla IV: Inversiones | | | |
|---|---|---|---|
| **Inversiones** | | **Totales** | **Pendiente** |
| Casas de Guardepaques | 206 | 4,841,000 | 4,841,000 |
| Vehículos | 94 | 2,350,000 | 2,350,000 |
| Centros de Uso Múltiple | 1 | 262,650 | 262,650 |
| Centros de Visitantes | 4 | 1,687,400 | 1,687,400 |
| Senderos | 734 | 1,980,910 | 1,980,910 |
| Planes de manejo | 32 | 917,088 | 917,088 |
| Oficinas Regionales | 7 | 1,400,000 | 0 |
| Sede | 1 | 250,000 | 0 |

**Figure 19**: Recurrent and investment needs are estimated in MICOSYS. The system can clarify how much of the investment needs has already been materialised.

**Not included**

The enhancement of sustainable use of the natural resources and cessation of the advance and expansion of the agricultural frontier in the bufferzones and biological corridor areas outside the core protected areas require many interventions of a very different nature. The programmes needed to put the necessary mechanisms of sustainable development in place are far different from those needed to manage core protected areas. They require agricultural extension and agroforestry interventions, and sometimes, even health and social programmes. Such programmes require inputs of a very different technical nature, which is available in institutions related to the ministries of agriculture and forestry departments. For successful implementation and technology transfer, NGO and community participation is crucial. Interventions of such nature in the buffer zones and biological corridors are not vested efficiently with a management unit for biodiversity conservation, but rather with institutions specialised in those fields. As the management success of both types of areas depends on a full integration of both core areas and their bufferzones, the coordination function can be carried out by the area administration. No budget lines have been created for specific expenditure related to activities of extension of sustainable agriculture and social services in bufferzones and biological corridors or their coordination with the parks administration. They are assumed normal tasks of the administration and must be carried out as part of their work.

Biodiversity conservation may be directed at many values of different characteristics and levels of relevance. Within bufferzones and biological corridors, the intensive interaction of society and biodiversity would need area specific platforms for a continuous dialogue between the management unit and the stakeholders involved. In each area, the stakeholders should be allowed to choose, whether to vest the coordination with the management unit or with a representative of the local stakeholders.

### 4.7.3. Some observations on the over-all costs

Wherever MICOSYS was used, the results of the financial component have caught a lot of attention. When confronted with the data, there usually is disbelief at first. Some think the costs are exaggerated, while others believe them to be underestimated. The convenience of the programme is in simple changes of com-

mon factors allowing the variation of parameters and indices. Since the programme is so simple to use, the users can play with it themselves, argue back and forth among themselves, until they reach agreement on the parameters. Invariably, politicians and political appointees are shocked by the height of the costs and ask if the costs can be reduced or privatised. Unfortunately, the private sector prefers to privatise the benefits, not the costs. The benefits, however, are usually already privatised, and lie with the environmental services, like tourism and water production. Martínez et al. 2002, has convincingly demonstrated how big those benefits are for the tourism sector in Central America. Unfortunately, the costs cannot easily be charged to commercial beneficiaries. Conservationists on the other hand usually ask if the personnel density is high enough. Scientists from universities ask why there is so little budget for research. The spreadsheet allows the different stakeholders to search an outcome by consensus through debating the levels of different factors of expenditure.

In the end, there will always be a figure that is much higher than the existing budget at that moment, including the temporary financing by international cooperation programmes. To deal with that situation, a follow-up study must be carried out to study and propose financing mechanisms. The options to deal with the situation vary widely from country to country and are not subject to any analysis in this document.

# 5. OPTIONS FOR MONITORING AND EVALUATION PROGRAMMES

Any policy for a given country requires its main actors (administrators, beneficiaries, stakeholders, politicians, citizens, NGOs, etc.) to be informed of its effectiveness (e.g. Cifuentes et al. 2000, Eagles 2002, Vreugdenhil and Smith 1998). This implies that the effects of the policy have to be measured and assessed continuously through a Monitoring and Evaluation (M&E) programme that is firmly embedded in the organisation and operation of the management administration (IME-consult 1987).

Ecosystem maps serving to compose protected areas systems are also quintessential as baseline information for monitoring programmes, reason to address monitoring in combination with protected areas system planning. The importance of such information may be illustrated by the USA National Parks Services (2002) that states that it "considers vegetation information arguably the most critical piece of information needed for park resource management and protection." The United States 240 national parks outside of Alaska have comprehensive vegetation[47] inventory and corresponding spatial information based on aerial photography; in Alaskan parks, vegetation and associated landcover features are being mapped from satellite imagery because of their large size. It provides "managers with a key measure on the status of the natural systems they are managing, such as:

- Management and protection of wildlife habitat;
- Modelling vegetation flammability and fuel loading implications for fire management;
- Analyses for site development suitability;
- Evaluation of resources at risk."

After having an map produced, efficient use of know-how and resources would make it desirable to organise an M&E programme that builds on and is compatible with the ecosystems map. This has been the reason to integrate protected areas system planning and monitoring.

The challenges of an M&E programme include:

- Selection of parameters which reflect the effects generated by the policy;
- Organisation of a monitoring program tailored to the execution measurements of the policy;
- Long-term continuation of the program.

Most wealthy countries have elaborate databases and related protocols to collect and store ecological data. Usually those systems are heavily centralised, and their use is dependent on database administrators. In many developing countries, NGOs, universities and government institutions have also started to build centralised databases. Considering that many biologists like to keep their own data in an independently functioning programme, the database for the Ecosystems Map of Central America was designed in MS Access so that each user may keep and interpret his/her own data. It has been designed to be very user-friendly so that it can be used by field biologists and protected areas field staff who have no prior knowledge of GIS and complex database operations. It can be operated independently of an institutionalised centrally administered database. The database has been tested by more than a dozen of scientists, who entered data from more that 1,500 relevés. Although originally designed for a tropical country, the database constitutes a tool for underpinning ecosystem mapping in any part of the world, including aquatic ecosystems. Complemented with management information, it may be used for protected areas monitoring programmes. Technical details and operation instructions must be consulted from the "Ecosystems and Protected Areas Monitoring Database Manual" (Vreugdenhil et al. 2003). Social, socio-economical and administrative monitoring requires complementary actions, which are not dealt with in this document. PROARCA/CAPAS (Courrau 1999, Cifuente et al. 2000) have designed user-friendly methods, which may be used to complement the application here presented.

## 5.1. PRINCIPAL USERS

An M&E programme should be oriented to the needs of the principal users, whose potential information needs may consist of the following:

**Ministers of Agriculture, of Natural Resources and/or of Environment** need information to enable them to formulate, adapt and defend their biodiversity conservation policies before the general public and specific actors (NGOs), and to defend / justify the related government budget;

**The director of the national administration of protected areas** needs information to make decisions on the administrative and organisational management of the SINAPH;

**Bi- and multilateral financing agencies** require information on the progress of the projects they finance and on the impact of their programs on the sector of intervention, in order to justify these investments before their board of directors (national representatives of international organisations or foreign ministers in the cases of bilateral cooperation entities);

**The directors** of each protected area need information on the impact of their interventions on the local actors to justify specific measures (both positive measures which promote economic benefits as well as corrective measures). They also need timely information on changes and threats in order to respond accordingly;

**The "scientific world"** needs verifiable and statistically sound ecological data for scientific research which advances ecological knowledge

[47] Much of that information has been mapped with the USA standard (FGDC, 1997) procedure of the USNVC system, whose classes have been argued to represent ecosystems.

and understanding, with benefits for humankind and better long-term management;

**NGOs** require information to assess the impact of government programs and to apply pressure according to their point of view (which may differ from one NGO to another);

**Local actors** (ethnic groups and farmers) demand transparency and information to enable them to participate in decision-making processes related to management programs, which may well have a bearing on their rights, economic opportunities and cultural life;

**The tourist sector** requires information for its clients, as well as for marketing purposes, needs may include data on environmental tolerance, best visitation options, information about presence and condition of biodiversity, etc.;

**Project executors** require data on the effects of their projects, whether they are development or infrastructure projects. In the case of the latter, the data that have already been collected for an area may serve an in-depth baseline for an environmental impact study. In the context of the project, the program for the measurement of impact would be intensified.

## 5.2. THREAT AND IMPACT RELATED MONITORING

An M&E programme cannot be designed without considering the different categories of threats to and impacts on the protected areas (Forsyth and Vreugdenhil 1996, Eagles et al. 2002). To assure the most effective data collection for management, each protected area in principle should carry out its monitoring as a decentralised unit, with an independent monitoring programme.

Many threats may stem from misunderstandings between local communities and protected area administrations. To reduce stress between protected areas programmes and neighbouring communities, it is critical to develop cooperative programs with nearby communities. One cannot ignore, however, that there will always be conflicts of interests with individuals, communities or groups with special interests who wish to modify and make use of protected areas to their own advantage vis-à-vis common benefits. This may result in activities harmful to the biodiversity of those areas. A M&E programme must focus on threats of this nature and give the administration an early warning so that it can respond on the basis of adequate and timely information. Response must first have a positive problem solving approach; repressive measures must be of last resort. Apart from that, natural forces may cause biodiversity loss. Finally, society's appreciation of nature may pose threats when visitation leads to unacceptable change. Some of the most common threats include:

- Transformation of natural habitat for agro-production purposes;
- Illegal exploitation of forests;
- Destruction of ecosystems by natural forces;
- Loss of key organisms because of poaching, illegal commerce of wildlife and over-fishing;
- Over-visitation by visitors;
- Fires;
- Pollution / contamination ;
- Climate change;
- Exotic species and disease.

It should be noted that these categories refer to direct phenomena, not to their causes. For example, a road may very well improve the access to a forest, which in turn may lead to deforestation. In this case, the direct phenomenon will be registered as habitat transformation or illegal exploitation, irrespective of the cause. If so desired, it is up to the users of the data to correlate observed phenomena with their root causes.

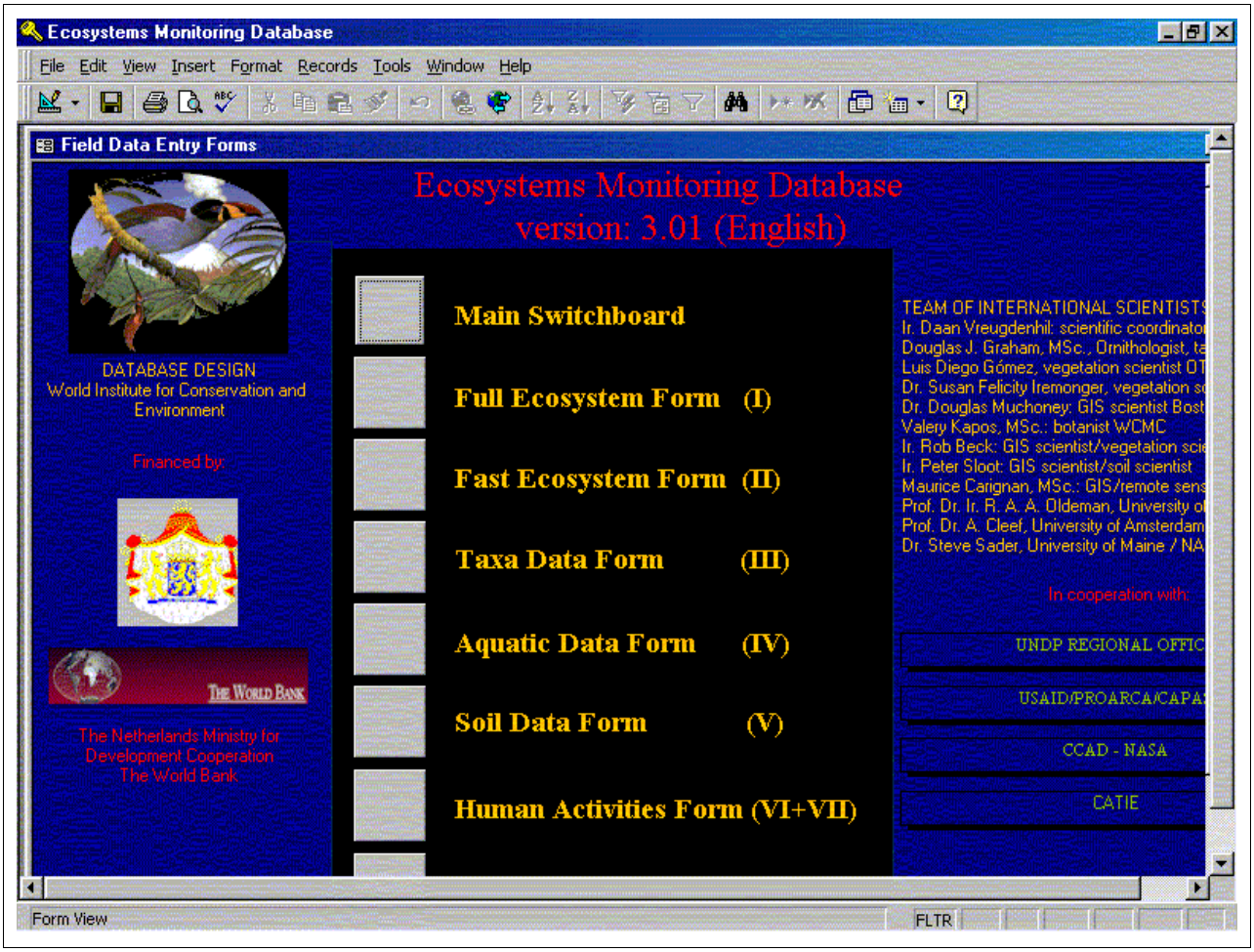



**Figure 20: Available data tables in the Ecosystems Monitoring Database.** The database has been expanded to store fauna and land-use data related to protected areas. The different data can be conveniently entered through interface forms that are almost identical to paper field forms.

## 5.3. CHALLENGES

Above all, an M&E programme should provide information for park management and most and for all, the information produced should serve the decision process to maintain the areas in a good state of conservation. An M&E programme should thus comply with the following characteristics:

- Have low costs and be highly cost-efficient;
- Facilitate rapid management and administrative response to observed changes in the field and new threats;
- Incorporate field personnel;
- Be transparent and verifiable, internally and externally;
- Be designed through a participatory process, involving the primary users of information.

Protected area management administrations everywhere are subject to strong pressure to execute costly research studies and M&E programmes. Main actors (scientists, NGOs, international donors, etc.) in countries all over the world recognize the need for a monitoring programme, but each one wants its own particular parameters of interest to be monitored. It will never be possible to satisfy the needs of all the users, and it will always be necessary to decide which data, for which users, can be generated by a general M&E programme. As they compete for financing with other management tasks, care must be taken; their costs don't lean too heavily on the overall budget.

Particular attention should be paid to the selection of species and parameters to be monitored. Some threat and impact related factors could only be detected by monitoring organisms, while others can more effectively and more economically be detected through direct management. A good example is deforestation, which can be measured directly and very cost-effectively, both in the field and from satellite imagery. As surveys are expensive and time consuming, animal indicators should be used only when direct measurement is impossible or costly (Azevedo-Ramos et al. 2002). After all, it does not make sense to measure a threat or impact related factor through indirect indicators, if direct measurement is cheaper and/or more precise.

Many taxa have been proposed as indicators of environmental health. However, the very reasons that raise a taxon to the status of a good indicator are not always well presented in the studies (Hilty & Merenlender

2000). Authors, generally, defend the use of a given taxon as an indicator providing a list of several attributes (e.g. specialist behaviour, sensitive to habitat changes, broad distribution) but do not always clearly state what the proposed indicator actually indicates. Few studies address the essential issue of the correlation between indicator status and changes in environmental variables (Hilty & Merenlender 2000). Monitoring programmes for natural habitat would need to focus on early warning characteristics and in areas or zones of use (forest exploitation, visitation) on facilitating the assessment of the acceptable degree of habitat modification (Azevedo-Ramos et al. 2002).

## 5.4. STAFF BASED PROGRAMME

When unacceptable change takes place, a management administration needs to attempt to halt the change expeditiously. Some causes may require a simple action by field staff, but some actions to terminate impacts may have political implications. Therefore, an M&E programme requires a well-thought structure that warrants timely observation of sudden change and effective communication between field observers and the right level of decision-makers. This requires effective integration of the programme into the overall management of the protected area (Eagles 2002), particularly by involving the most abundant staff category of any protected area administration, the rangers.

### The Rangers

The main factor of *in-situ* conservation of the ecological integrity of protected areas is the physical presence of rangers (Bruner 2001). In the "Global Environment Monitoring System" of UNEP, Loth 1990, considers rangers essential when working in national parks or reserves. Because of their ubiquitous and frequent presence in the field, rangers are the most effective source of observation of sudden change and the all-round conservation status of protected areas. They are the eyes and ears of a protected areas administration. Rangers are not only observers; they are also the first line of defence against unacceptable change (Vreugdenhil and Smith, 1998). They can take immediate action against poachers or individuals that illegally fell trees or set fires.

Furthermore, their work involves interaction with society (communities, visitors, scientists, etc.) and conservation directly through positive interaction with the actors. They are also part of the direct liaison with local communities and may detect conflict before it leads to infractions and physical change in the field. As mediators, they may prevent and solve many problems between their area and neighbouring communities. For any protected areas system, this is the quintessential component of monitoring. Any M&E programme, which is based primarily on professional scientific observers, would lack the effectiveness of this "observe and act" M&E organisation. As the observations on human activities is very important for decision-making and the evaluation of management effectiveness, rangers should properly record their observations and the information needs to be entered in a database. That information can become even more important if it can be related to biological data. The database has been designed to facilitate such analyses.

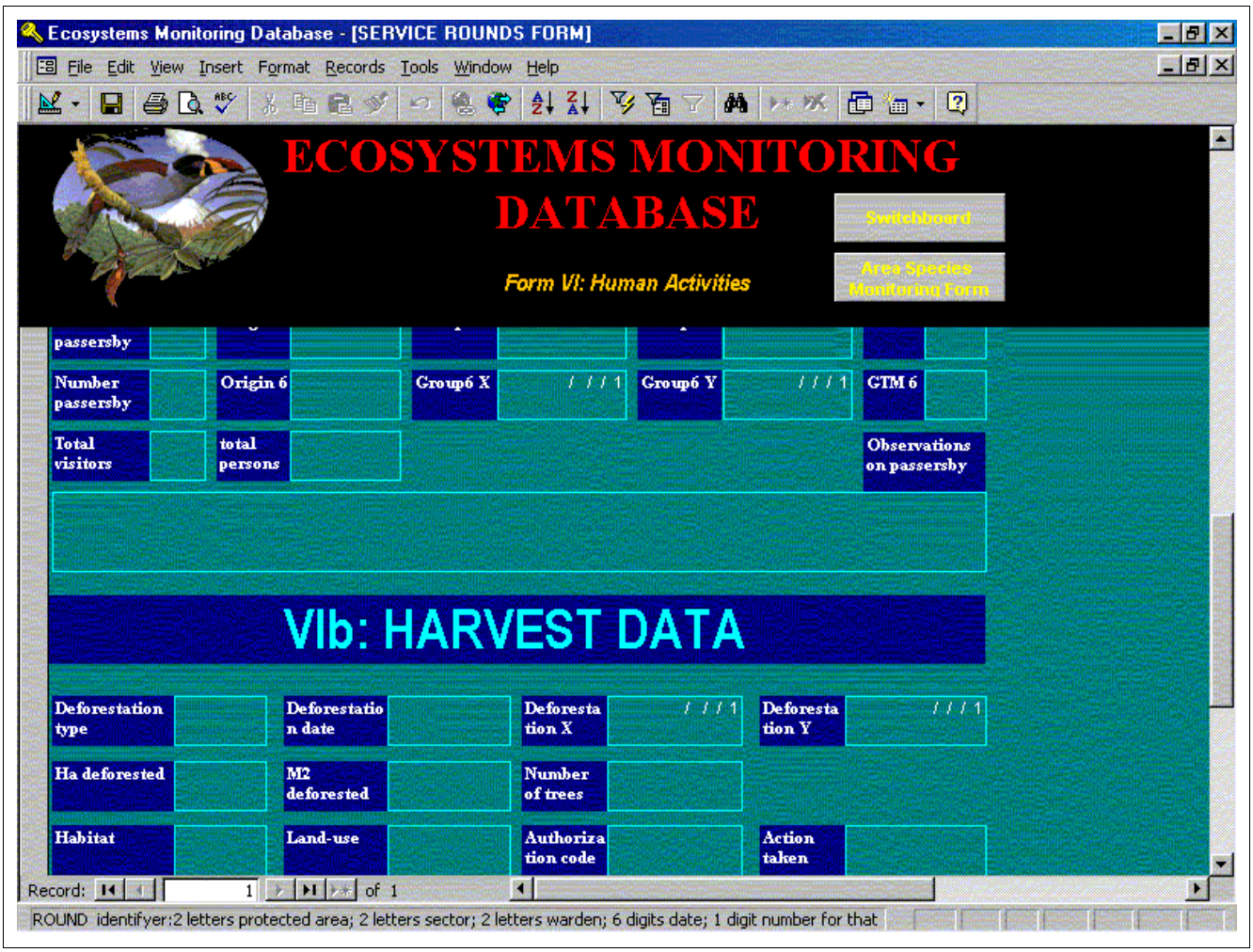



**Figure 21: Data on human activities to be collected by rangers**. Land-used data for protected areas focus on visitor information and change in the bufferzones.

To firmly institutionalise the integrated role of public service, monitoring and law-enforcement assigned to rangers, their job descriptions should rule that their primary task is to carry out periodical rounds. They should routinely frequent their sector(s) of their area and its neighbouring zones, collecting information, serving the public and enforcing the law (MacKinnon et al. 1986). It should state clearly that they have to spend the better part of their workweek doing their rounds, collecting and storing field information and spending time interfacing with neighbouring communities. Where this is not the case, their job descriptions and work practices need to be modified to highlight a new and rigorous routine of service (Forsyth and Vreugdenhil 1997, Vreugdenhil and Smith 1997).

To achieve this, the directors or chiefs of the rangers must prepare service plans to cover all areas of the park and neighbouring zones. Typically, the plans must include routes to follow, periodical programmes for the monitoring of transects, itineraries for personnel, monitoring in cooperation with NGOs and specific monitoring contracts, etc. They should define the hierarchical line of communication, including the circumstances under which the ranger is allowed and expected to directly contact his director, request support from the police, the M&E coordinator, etc.

It should be clear that law enforcement only makes up a fraction of the work of a ranger; in many protected areas, with sufficient fieldstaff, infractions only occur sporadically and in such cases, a conversation with the offender or a meeting with the neighbouring community may structurally solve the problem. Yet, a ranger should have the authority to take legal action if the situation would require as much.

The routines in the border and bufferzones should emphasise the role of rangers as service providers. As such, they are the park ambassadors and the liaison staff between the protected area and the local communities. They should be respected, and thus, need training in community relations and socially acceptable behaviour and always be properly uniformed when on duty.

**The M&E Coordinator**

To enhance the professional nature of the M&E programme in the selection of information to be monitored, the storage and compatibility of data, and the assessment and appropriate reporting of the information, a full-time academic is required (preferably a biologist with knowledge on computer programming), specialised in monitoring and management of information systems. This person should be in charge of the

data collection protocols and analysis of the organisation. He/she works closely with the rangers and the directors, assisting in the collection of consistent, uniform, high-quality information. This position should be included in the central administration at a high level, reporting directly to the director of the protected areas administration, serving as his/her ears and eyes and advisor. It should be emphasised, however, that the coordinator must also pay at least an annual visit to each one of the more important protected areas of the system for periods of time long enough to provide technical leadership to the rangers and carry out an in-depth collection of data. In the case of large countries with many protected areas, the task of M&E Coordination may require spreading over various persons and executed from various regional administrative areas. An energetic person who is able to directly verify the status of the biodiversity must fill the position. His/her background MUST be in field biology, while complementary training in database management will usually be required. The M&E coordinator will actually work as a permanent trainer and evaluator for the rangers.

**The Directors of the Protected Areas**

At a third level, the information collected by the rangers must be analysed and reported directly to the area director. He/she can then decide whether a particular action is justified and the nature of the action. In any event, the ranger who reported the irregularity should always be informed about his/her decision within a period of time no greater than a week. This type of feedback to the rangers is very important for the development of their judgement capabilities, assessment of the relevance of their observations and for incentive purposes. With regard to extraordinary events, the area director takes the decision on when to inform the national director. He is also responsible for the preparation of an annual monitoring report of his/her area.

Many times, personnel voice interesting observations, ideas and opinions that never make it to the decision-making level. Former director of a U.S. national park, Richard Smith (pers. com.) told how he would invite staff of different levels of his team to talk with him about their experiences and opinions with the parks administration. This type of "monitoring" can be very useful even though it is not statistical or systematic, nor can it be incorporated very easily into a database.

## 5.5. COOPERATIVE PROGRAMMES

Inspection flights are recommended at an altitude of around 300m to cover the perimeters of all prioritised protected areas. For Latin America, it is probably possible to obtain flight programmes from the NGO "Lighthawk" (http://lighthawk.org). Flights may involve the national director of the administration, the M&E coordinator, and the directors of each area to be flown over, along with their chief ranger. This would be an aerial verification of the information collected on land by the rangers. It would probably be worthwhile to photograph areas threatened by invasions. There are camera systems with GPS positioning which can be mounted on the wings of the aircraft for this type of observation.

Universities need to take their students out into the field. Often the financial means for such activities are very limited (Vreugdenhil 2001). A very productive way of collaboration is when the protected areas administration collaborates with universities by providing any or all of the following elements to universities: transportation to protected areas, food, lodging, sampling field equipment, a computer with the administration's monitoring database, etc. Such collaboration needs to be properly defined through a signed agreement. In this document it should be clearly stated that all the information resulting from the collaboration becomes publicly accessible, and that the database used for the storage of information may be publicly consulted.

In several countries, programmes exist for voluntary rangers (e.g. Mexico and Costa Rica, according to Vreugdenhil and Smith 1998). Such voluntary rangers should also be fully involved in a monitoring programme. Additionally, information may be acquired regarding social impacts, socio-economic benefits, etc. For different elements, park administrations need to work together with local communities and stakeholders, such as tourist operators. Some forms of data-collecting may be achieved through collaborative actions.

There are excellent nature observers among park visitors, and the administration may hand out standardised forms (Eagles 2002) with different degrees of specialisation on biological observation. Care must be taken, of course, to establish a mechanism of distinguishing between the different levels of observation capacity of the observers. A very productive programme may be to make arrangements with eco-tourism operators to periodically organise an intensive monitoring programme under the guidance of an experienced biologist.

## 5.6. COMPLEMENTARY AD-HOC EVALUATIONS

The analysis of satellite images with a GIS programme enables the monitoring of the deforestation process and the comparison with historic situations. The application facilitates the computerised detection of changes in vegetation coverage and a clear visual presentation. The applications still have their limitations though, and should be used in combination with other forms of monitoring, most notably ranger-based monitoring. One of the main limitations of GIS applications is in their slow reaction to the situation in the field. GIS based monitoring requires satellite image taking, analysis of the availability of new images on the Internet, purchase, shipping to the country, GIS analysis, and reporting to responsible parties. The process of GIS analysis begins with the LANDSAT 7 satellite taking an image of the zone that covers a protected area. Its orbit profile operates on a repetitive 16-day cycle (http://ltpwww.gsfc.nasa.gov/IAS/handbook/handbook_htmls/chapter2/chapter2.html, 2002), the successful

shooting of an image may take up to 16 days after the event took place; in humid tropical regions, this may take considerably longer because of cloudy conditions. Once an image has been identified, usually several months go by between the shooting and the purchase of the image and shipment and custom clearance will take up to a month. At least one or sometimes two years go by between the moment of a new deforestation and its discovery by means of a GIS analysis on the basis of satellite imagery. After such a long time interval, the situation has been consolidated, and therefore, may no longer leave much room to solve problems and take appropriate measures in the field. Apart from the time limitation, at the scale that the images (such as LANDSAT 7) are taken, partial and small-scale deforestations are frequently below the detection level and will go unnoticed. In conservation, it is essential to stop new deforestation in its tracks as soon as it takes place to prevent it from inducing new squatters to come in.

Satellite imagery based GIS analysis does provide important information for programme effectiveness analysis, documentation and historical analysis and is suitable for understanding the results of a project, management programme and/or conservation policies in the medium- and long-term. Furthermore, GIS analysis is particularly suitable and indispensable for ecosystem identification and mapping, and in combination with forest cover change-detection analysis, it may be used to prioritise future management attention and project funding needs.

**Limits of acceptable change**

To avoid the creation of artificial visitations limits based on artificial formulas, it is advisable to substitute carrying capacity studies for a modern adaptive policy of "**limits of acceptable change**" (Vreugdenhil and Smith 1998), which involves a permanent monitoring and evaluation process of the impacts and the implementation of mitigation measures necessary to maintain the changes in acceptable conditions. The indicators must be bio-physical (part of the species indicator game, animal behaviour, damages to coral reefs), and social (surveys). The administrators then have to establish standards on what type of change is acceptable before adopting new management strategies. For example, if the visitors say that there are too many people on the trails or the rangers report erosion of the trails, the administrators can modify the strategies to reduce the number of visitors allowed on the trails, change the routes or pave frequented trails. A "limits of acceptable change" policy requires that the administrators have good information available on the resources, that they define changes that are acceptable, that they monitor the use, and that they recognize if the limits are exceeded. Since the experience of the public varies, and infrastructure measures have a bearing on ecological sensitivity, the administrators must adopt new management strategies and assess and redefine the "limits of acceptable change" each time new significant changes occur, so that the conditions of the resources and the experiences of the visitors fall again within these limits.

In order to follow the ecological impact of visitations, both on the local and regional economy, it is useful to have a standardised system for registering the number of admissions to protected areas. A practical method is through the sales and issuance of entrance tickets. Meticulous registration, not only provides financial accountability, but also information on visitation. If the central office provides the tickets (in rolls or receipt-books, for example) and keeps a record of how many tickets have been issued for each protected area and it monitors how many are actually used, the administration obtains sound statistics on visitation. As long as an entrance charge is not feasible, it is important that the number of visitors be counted. In highly visited sites, at least yearly assessments must be made of the state of the trails, trampling, erosion and other effects from visitation. The M&E coordinator and the park directors need to take these factors into account in their annual planning.

## 5.7. SOME WORDS ON MONITORING MANAGEMENT EFFECTIVENESS

In 1995, the WCPA established a task force to explore issues related to the management effectiveness of protected areas. Important contributions came Cifuentes et al. (1999) http://www.iucn.org/themes/forests/protectedareas/MaindocCatieProceedings.pdf from the WWF regional office for Latin America. Based on the results of the task force's findings, the WCPA has developed an overall assessment framework (Hockings et al. 2000) in order to provide a consistent approach to assessing protected area management effectiveness. The WCPA Framework is based on the management cycle illustrated in table 10. It includes six main assessment elements: context, planning, inputs, processes, outputs, and outcomes.

The World Wide Fund for nature designed a methodology that is one of several ongoing efforts to develop specific assessment tools that are consistent with the WCPA Framework: the Rapid Assessment and Prioritisation of Protected Area Management (RAPPAM) Methodology (Erwin 2003). The methodology primarily focuses on protected areas systems. The methodology can be downloaded from http://www.panda.org/downloads/forests/rappam.pdf and comprises a set of forms to carry out the assessment. Together the forms cover each of these elements, and are organized in accordance with the WCPA framework, illustrated in Table 10.

In general, the RAPPAM Methodology is designed for broad-level comparisons among many protected areas. It can answer a number of important questions: What are the threats facing a number of protected areas and how serious are they? How do protected areas compare with one another in terms of infrastructure and management capacity? What is the urgency for taking actions in each protected area? What is the overall level of integrity and degradation of each protected area? How well do national and local policies support the

effective management of protected areas? What are the most strategic interventions to improve the entire system? Although it can be applied to a single protected area, the RAPPAM Methodology is not designed to provide detailed, site-level adaptive management guidance to protected area managers. An in-depth field assessment can answer detailed site-specific questions, such as the following: What specific steps are needed to prevent or mitigate existing threats within each protected area? What are the specific needs for each protected area regarding training, capacity building, and infrastructure support? How well is the protected area managing its specific biodiversity assets?

**Table 10: Evaluation Framework (Hockings et al. 2000)**

| Elements of evaluation | Context | Planning | Input | Process | Output | Outcome |
|---|---|---|---|---|---|---|
| Explanation | Where are we now?<br><br>Assessment of importance, threats and policy environment | Where do we want to be?<br><br>Assessment of PA design and planning | What do we need?<br><br>Assessment of resources needed to carry out management | How do we go about it?<br><br>Assessment of way in which management is conducted. | What were the results?<br><br>An assessment of the implementation of management programs and actions;<br><br>delivery of products and services | What did we achieve?<br><br>An assessment of the outcomes and the extent to which they achieved objectives |
| Criteria that are assessed | Significance<br><br>Threats Vulnerability<br><br>National context | Protected area legislation and policy Protected area system design<br><br>Reserve design Management planning | Resourcing of agency<br><br>Resourcing of site Partners | Suitability of management processes | Results of management actions Services and products | Impacts: effects of management in relation to objectives |
| Focus evaluation | Status | Appropriateness | Resources | Efficiency Appropriateness | Effectiveness | Effectiveness Appropriateness |

Cifuentes et al. (2000) designed a booklet to measure the management effectiveness of protected areas, which includes a set of forms to weight the different evaluation parameters. The method is designed to work for individual protected areas. http://www.panda.org/downloads/forests/measuring_effectiveness.pdf (English) or http://www.iucn.org/themes/forests/protectedareas/Medicion.PDF (Spanish).

On the same principles, Courrau (1999) developed a method for Central America on behalf of PROARCA/CAPAS, also including a set of forms to weight the different evaluation parameters: http://www.iucn.org/themes/wcpa/wpc2003/pdfs/streamleads/ManagementEffectiveness.pdf . The forms that go with the document have been integrated into a user-friendly programme in MS Access, which has been customised for several protected areas systems in Central America. COHDEFOR/DAPVS has permitted to host the Honduras file for downloading on: http://www.birdlist.org/nature_management/national_parks/national_parks_systems_development.htm. Please note that the posted file has tentative and possibly dated data of Honduras. Its use for other countries requires some formatting and translation from Spanish.

These methods had been prepared in the context of the WCPA Task Force on Management Effectiveness to monitor and evaluate management effectiveness and particularly link the evaluation to stakeholders. These programmes do not monitor or evaluate protected areas systems on quantitative biological data or their surrogates. Aware of the existence of the programmes, the authors of the present document have not tried to duplicate these tools in any way, but rather they have worked toward a complementary programme. With regard to the management effectiveness methods, it seems opportune to suggest the following. For budgetary and management planning purposes, it is paramount that a management unit and/or agency have a simple programme to register all equipment, buildings and infrastructure, and which allows the assessment of the state of maintenance, urgency of repair of replacement and estimated costs. It would be recommendable to have any of aforementioned management effective-

ness tools run in a computer programme in which a module is incorporated to register the state of maintenance.

## 5.8.ANNUAL MONITORING REPORTS

On the basis of field data of the protected areas, specific surveys and periodic administrative evaluation (Courrau 1999) of each of the protected areas of the system, the M&E coordinator must prepare an annual evaluation report, focusing on the achievements and failures of the programme. The national director must review it and distribute it on a wide scale to NGOs, interested communities and other government institutions. This report can provide the basis for recommendations and interventions at cabinet and legislative levels. It should likewise serve as one of the several criteria for the assessment of the performance of each director and the status of the conservation of each protected area.

The database has been designed to be able to store a very broad variety of data on species and ecosystems. The characteristics and sampling instructions are explained in detail in the Ecosystems and Protected Areas Monitoring Database Manual, Edition 4, (Vreugdenhil, et al. 2003).

## 5.9.COLLECTION OF DATA

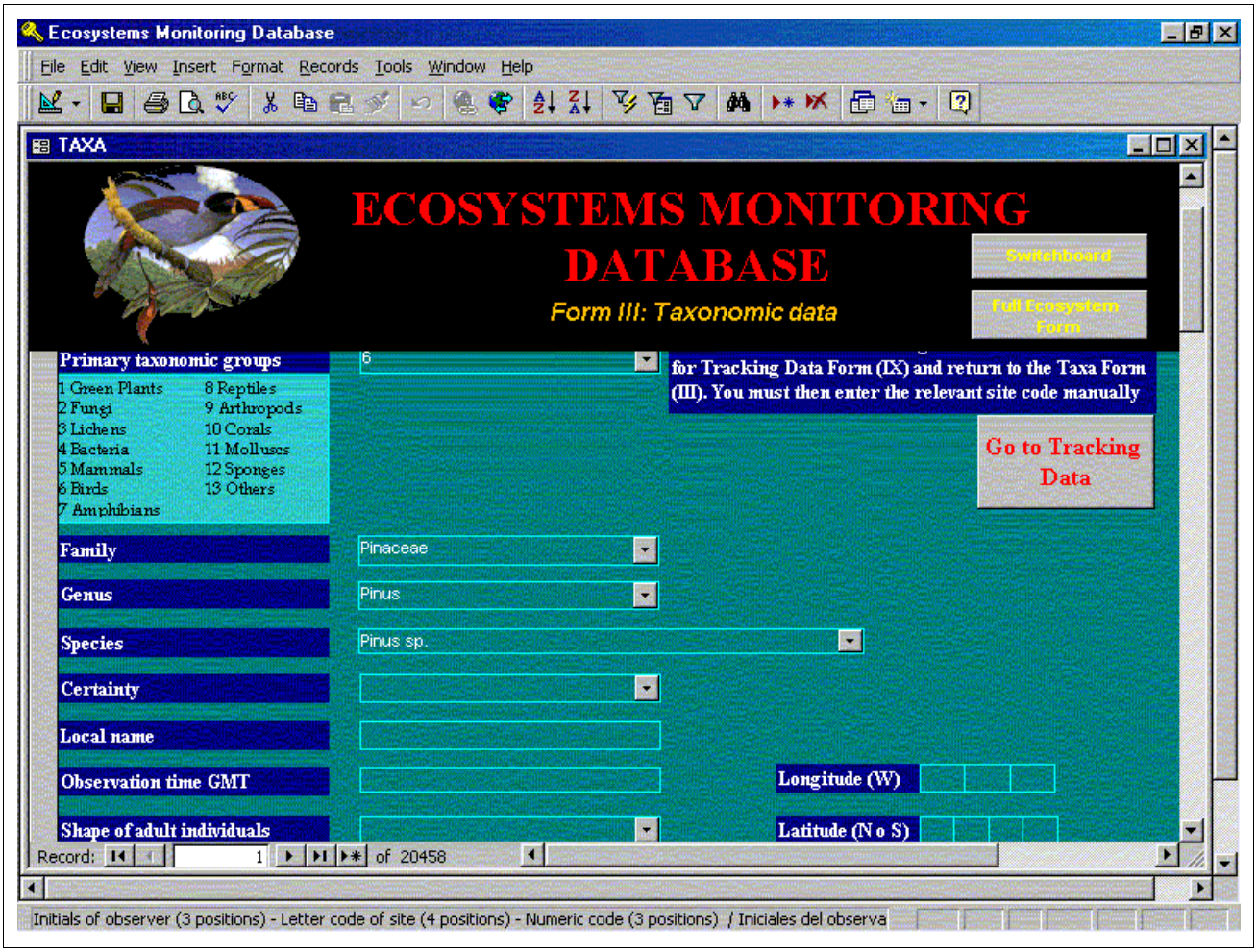



**Figure 22: Taxonomic data form in the Ecosystems Monitoring Database**. Species information essential information on flora, fauna and fungi. Its taxonomic information is somewhat less detailed than the information of a herbarium and should be used in complement to a herbarium database.

# 6. DISCUSSION

Articles 7, 8 and 9 of the CBD deal specifically with the biological aspects of the convention, while other articles deal with sovereignty, legal and social issues. This document makes an attempt to integrate the following key elements of the CBD:

- Identification;
- Design of Protected Areas Systems, including cost considerations;
- Monitoring of biodiversity in protected areas.

**ON IDENTIFICATION**

Natural ecosystems are shrinking rapidly everywhere, making the development of national protected areas systems a very urgent process, while financing for biodiversity conservation – although increase since 1992 – remains short in supply. Most countries in the world have started setting aside protected areas or protected areas systems, but it appears from literature review that for the tropics, methods for detailed identification of biodiversity-by-proxy have not yet been available until very recently. Without such method selecting biodiversity to protected areas systems systematically is not possible, and therefore, it is unlikely that protected areas systems in many developing countries have been composed optimally. What are the essential characteristics for an identification method to qualify for selecting biodiversity to protected areas system, and does the proposed method comply with the requirements to select both species and ecosystems?

**Identification of biodiversity by proxy**

It has been argued that it is impossible to identify all 3 – 10 million species of the world and establish their distribution in time to select them to protected areas systems. Therefore, a selection-by-proxy method is necessary. Does the proposed methodology of physiognomic-ecological classification system meet the requirements and are there any alternatives? It is argued that of the methods reviewed, the UNESCO-classification system, the USNVC and the LCCS each qualify for that purpose, as the different classifying characteristics or modifiers each facilitate the presence of species with different survival strategies. Enriched with other modifiers, particularly biogeographical, floristic characteristics and information on the distribution of individual species (e.g. endemism), the areas identified with these systems may be considered ecosystems with distinct assemblages of species. Caution is required, because the collection of much of that kind of information risks being biased by access, distribution of research facilities and fields of specialisation of researchers.

**Ecosystem mapping within foreseeable time and at manageable costs**

As funding for research is scarce, and the time for selecting natural areas to protected areas is running out, a method needs to be affordable and executable within a foreseeable period of time. The production of the Map of the Ecosystems of Central America has demonstrated that a map with about 140 different ecosystem classes can be produced in a period of one year of computer analysis and fieldwork plus another year of data processing and report writing. This should be considered as an acceptable period for identification of biodiversity. The costs involved were about US $2,000,000, or US $280,000 per country. However, considerable funding has been spent on the learning and experimenting process, and future applications in other countries can be considerably more economical if use were made from the lessons learned. Also, the reduction in price of satellite images from LANDSAT 7, which now cost less than 10 percent of previous images, will make future productions more affordable. Given the importance of identification and the availability and significance of the data as baseline information for monitoring, this document concludes that the identification through ecosystem mapping is affordable and recommendable for protected areas system analysis purposes, using aforementioned classifications systems. Given its design to work with GIS, it may be expected that the LCCS will become the internationally most commonly applied system.

Reproducible techniques and maximum involvement of national conservation scientists

Scientific data not only need to be internationally accepted - which is the case for the physiognomic ecological classification systems – but also, they need to be "owned" by national scientists. To achieve the former, it is very important that the mapmaking be done as much as possible by – or at least involving – local biologists. The aforementioned study has demonstrated that this is very well possible, and it is recommended that mapping projects be designed to hire local biologists and train them to actually map their own maps.

**ON LOW DENSITY SPECIES**

In the context of this study a variety of botanists with extensive experience have been consulted on the possible occurrence of trees with densities comparable to those of the world's largest terrestrial predators (e.g. S. Mori, H. van der Werff, D. Daly, A.M. Cleef, J. Luteyn, pers. com., J. Terborgh, J. Duivenvoorden). What has emerged is the following. In temperate climate and tropical savannah conditions not trees occur in densities lower than 1 per 100 ha throughout their ranges, and if trees with lower densities exist, it must be in the tropics. As trees (and plants) are fixed, they can only be observed on their specific location. Current information on their effective population densities – taken as trees of 10 cm. dbh – can only emerge from complete tree-inventories of plots, which is a highly labour intensive exercise. Plots are usually not taken beyond 100 ha and the lowest densities can only be assessed from analysis of accumulative plots. E.g. if a tree only occurs once in a variety of samples, we can't say more than that that particular species may have a density of about the accumulated plot sizes or lower, but not how much lower. The consulted botanists could not answer the question if from their experience trees with extremely low densities exist, as research has not been focussed at that topic, but it appears that at least some trees that occur in low densities in some areas, may

occur in much higher densities elsewhere. In the latter case, - if specific low-density trees require special attention – areas with their highest known densities would of course be of high priority for securing their survival. As the knowledge of the densities of low-density trees is essential for their conservation, a specific study is required for humid tropical forests of all tropical regions to assess the densities of the lowest density trees, with as a first step, the analysis of existing databases to identify potential candidates for further analysis.

Animals in need of large territories are relatively few and information on low-density species is very important for protected areas composition analysis; it is recommended that a study be carried out to identify all low-density species with their current occurrence densities. In general, a number of long-term strategic studies are needed to better understand the ecology of top-predators on each of the developing and transition continents. As information becomes available on both plant- and animal low-density species, it will be posted on:
http://www.birdlist.org/nature_management/national_parks/national_parks_systems_development.htm and scientists are invited to share their studies for publications on this site.

**ON PROTECTED AREAS SYSTEM COMPOSITION**

With conservation funding being scarce and land-pressure mounting in most countries of the world, this document observes the need for the composition of protected areas systems, which would optimise efforts for durable conservation by seeking out as many species as possible on as little territoire as possible. In order to achieve this objective, it has set a number of criteria for composing ecologically reasonably stable protected areas systems. To which extent can those criteria contribute to more effective selection of species and ecosystems? How little land can we set aside and still hope to preserve the species durably?

A minimum of 10 percent – the target of the III$^{rd}$ World Parks Congress in Bali - of the national territory protected under strict biodiversity conservation legislation and management with no human occupation or land use other than non-consumptive environmental services: Assuming that species would be distributed homogeneously across the landscape, 10 percent territory would protect about 70 percent of the species if $z$ = 0.15 or 50 percent if $z$ = 0.3. As many species are only more or less evenly distributed as different assemblages within (a) certain ecosystems, this may only be achieved if species assemblages be selected as a minimum of 10 percent of each ecosystem. This requires the availability of a reasonably detailed ecosystems map. Without selection through such map a country is likely to lose more species than necessary.

An effective minimum population at 500 individuals: This model is subject to considerable theoretical criticism and authors can be found that claim the need for one or two orders of magnitude larger. However, the proposed criteria deal with each population as though it were the last on earth, which in most cases it is not, because the criteria are set hoping that something similar be done in every country in the world. The risk of extinction decreases significantly if a species has a population protected in different countries, thus allowing for re-introduction after local extinction. Particularly the risk of disasters decreases with regional spreading of small populations. The effects of inbreeding recession may be simply avoided by exchanging a male every few years among isolated populations.

Many authors claim that a few hundred years is not enough. After all, we try to conserve those species – humanly speaking – forever. This is true, but we cannot look into the future. If mankind finds ways to somehow redistribute wealth and well-being more equitatively, peace and conservation may both benefit and grow, and conservation may remain a human concern. Alternatively, mankind may altogether lose its interest in conservation, in which case, anything we do now will be in vain. Assuming a positive scenario, it is interesting to consider some possible trends. Worldwide, we can observe a tremendous shift from rural dwelling to city dwelling; this can already be seen in some isolated mountain regions in Mexico and Costa Rica. If the trend of the native populations of the wealthy countries is any indication, the world population may decrease in the future and some agro-production lands may be converted again into ecosystems suitable for large animals. In short, there are so many factors of uncertainty, that it is not realistic to set targets for many hundreds or thousands of years resulting in requirements for vast protected areas systems, while current land-conflicts are so pressing. If today we can set conditions for the larger species to hold on to life for a few more centuries, we must simply hope that in the course of that period, mankind finds ways to extend that period to many millennia. This method pretends to at least give that option to future generations.

One protected area should have a minimum size of 1 percent of the territory of the country, where 1 – 1.5 million ha is the target to allow for MVPs of most large predators. Often this can only be achieved through combining "bi-national" parks along a border: 1 – 1.5 million ha is not enough for some of the larger species, particularly the predators. Fortunately, in each country, the number of animal species that are threatened in their survival is very small, and through periodical exchange of individual specimens, genetic variability may be conserved. When a large species locally becomes extinct, it may be replaced from whatever source is available. Purists might object that his kind of management is "unnatural", but this argument lacks force in today's world (Soulé 1987). For critical cases, captive breeding may be required and a new population may be re-introduced into the wild, after sufficient individuals have been raised in captivity. If there are tree species that require larger territories than available in a country, the problem of conservation may be more

complicated, if the species only tolerates natural pollination and seed-dispersal.

In addition to the protected areas system, many countries also have relatively wild areas for other purposes, particularly production forestry (IUCN category V and VI areas). Such areas usually serve as suitable additional habitat for large mammals and usually qualify to satisfy the territorial needs of the very-low-density species. If in such areas the hunting can be regulated to prohibit hunting of top-predators, those areas may qualify for conservation blocks for very-low-density species. However, consumptive-use forest areas (in the V and VI categories) cannot be counted to collect the same species diversity that their category I-IV counterparts can, particularly those with highly diverse natural ecosystems. The contribution of categories V and VI areas to conservation is highly dependent on their management regimens as well as the rigor solidity of the protective status of protected zones within such areas. Often the degree of protection of protected zones in category V and VI areas is highly subject to the ideas of managers and often changes with management staff.

**Incorporate 2 to 3 examples of each ecosystem in different areas at or above its minimum size or as an embedded ecosystem**: This criterion provides considerable added conservation security, as well as incremental protected area size. Through this criterion, additional land of more abundant ecosystems around the required ecosystems is usually added to the system. So far, in each country unique ecosystems have been found which only occur once or twice. Those rare ecosystems may be small, but require utmost care, as their destruction risk is far higher than of the more common ecosystems and their species.

**Minimum ecosystem sizes**: The concept of differentiated minimum ecosystem sizes is rather speculative and both the differentiation and minimum sizes are debatable. They have been selected intuitively while they should have been debated from the species-level up. This was found difficult to establish, since the different categories have so little in common. The concept has been proposed for the conservation of the majority of those species that depend on such ecosystem, but not all. Minimum ecosystem sizes usually cannot durably harbour large mammals when isolated by agro-production systems. They are meant to be buildingblocks, that depending on opportunity, together compose larger areas. The minimum ecosystem size concept has been established **in addition** to the minimum area criterion, established for the needs of populations of low-density species. They have also been established with moist tropical and temperate ecosystems in mind, and particularly, need further thinking for sub-polar and polar ecosystems.

**The integrity of watersheds encompassing protected aquatic ecosystems should be conserved through adequate management measures**: Limnic and brackish ecosystems are among the scarcest on earth and should be considered highly threatened. Even if locally protected in a protected area, these ecosystems and their species risk destruction from upstream sources, such as pollution, siltation and desiccation. This document recognises the problem, but cannot go into the detail of the issues that need to be dealt with for their conservation, other than considerations on minimum ecosystem sizes. Durable conservation strongly depends on the cooperation with other authorities with mandates of water management.

**ON PROTECTED AREAS WEIGHTING**

Composing a protected areas system requires the comparison of protected areas and potential protected areas. MICOSYS is a spreadsheet based analysis programme and has been designed for comparative weighting of the areas under study on the basis of a selection of ecological, taxonomical and socio-economical variables.

**Equal weighting of each criterion among all areas under study**: Each variable can be assigned a value or algorithm on the basis of a professional judgement; thus, each value by its very nature is subjective. But once established, the processing of each parameter is carried out mathematically and performed identically for each variable and each area. As the parameters become numbers, the MICOSYS facilitates the paradoxical exercise of "adding apples and oranges". In the end, it comes up with a numerical score for each evaluated area, which has come about by a consistent computing method. Such scores allow relative comparisons between the different areas.

**Adaptability**: Species-based biodiversity selection criteria occupy an explicit and important part in the application of MICOSYS, which is consistent with the CBD. Yet, even though the primacy of biodiversity and natural heritage values in ascribing protected area status is pre-eminent, many protected areas also serve to provide environmental services[48], notably tourism, recreation, production of drinking water, research and education. Where appropriate, the programme assigns the potential of the most common services a value. Some elements must be weighted that must be considered as threatening or negative elements in the evaluation and the programme may assign a negative value to such conditions. By default, the programme has been set up to weigh the following parameters of the areas of a national protected areas system:

- Size of the reserves;
- Size of the land/water under cultivation;
- Tourism value;
- Outstanding environmental education opportunities;
- Size of economically used parts of watersheds;
- Ecosystems representation;
- Geomorphologic highlights;
- Presence of extraordinarily scenic landscapes;
- Presence of archaeological remains;
- Representation of species of special concern.

[48] An extensive review of the functions of nature has been made by De Groot, 1992.

The programme has been designed to be extremely flexible and there is no limitation to either the number of factors to be weighted or the relative value attributed to a factor by simply adding a column and value for an additional factor.

**Transparent selection and procedures for professionals, interested non-professionals and politicians**: A protected areas system requires broad support from conservationists, whom in majority are not professional resource managers, which often is also the case for politicians. In order to achieve broad acceptance, the presentation of considerations of choice must be as comprehensive as possible. MICOSYS can be understood and manipulated by any person familiar with spreadsheets. It uses size data from a GIS, which can be obtained by a simple viewer, like ArcView 3.x. They may be requested from a GIS operator, but more and more biologists will learn how to work with GIS, particularly if they first have been involved in the production of a national ecosystem map. All the data required for MICOSYS can be entered by any biologist or natural resources planner. Once entered, the programme can be handed out to NGOs and individual conservationists, so that they themselves may vary the data and understand how different factors influence the outcome, and thus, may come to their own conclusions.

**Broad acceptance to the conservation community**: The analysis of areas and factors should ideally be carried out under the guidance of a broad-based national commission involving a representation of conservation gremia such as universities and conservation NGOs, as well as indigenous groups where applicable. Factors of validation as well as relative weighting between factors need to be approved by a broad-based national steering committee.

**ON BASIC COSTS**

The costs of a protected areas system is particularly related to the size of land under protection, although influenced by certain factors. The more land under conservation, the higher the costs, both for investment and for operation. The financial consequences of the amount of land incorporated in the system are significant for all developing countries and should be made clear, both for conservationists and for politicians/decision-makers, so that choices are not made lightly. By building in a financial module, MICOSYS enables stakeholders and decision-makers to become aware of the challenge of the road ahead and to make better-founded and conscious decisions and to develop financing strategies. E.g. Honduras needs about $5,000,000 per year (Vreugdenhil et al. 2002) and when choosing that particular module, conservation gremia as well as the Government were aware that a completely new financing approach was required. A proposed law dealing with a structural solution has been presented to Parliament (situation March, 2003, Archaga pers. com.). Similar estimates need to be made for all countries of the world, so that national governments can start working with bi- and multinational financing institutions to find ways to durably finance biodiversity conservation. It will become apparent that there is a major gap between available funds and funding needs. GEF funds provide an estimated $1,000,000,000 per year (World Bank 2002), but only a minor part of those funds is available for the core needs of protected areas administration, and if the case of Honduras is indicative of the most basic costs of protected areas systems, there could be a worldwide need for biodiversity conservation in assistance requiring nations of an order of magnitude higher than currently available. To close the financing gap, a two-tiered approach is needed from both international financiers and individual national governments. But unless costs estimates can be specified with reasonable accuracy, no significant progress is expected to be made in that field.

**COST-EFFECTIVE RESPONSIVE MONITORING**

Protected area management administrations everywhere are subject to strong pressure to execute costly research studies and monitoring and evaluation programs. Main actors (scientists, NGOs, international donors, etc.) in countries all over the world recognize the need for a monitoring programme, but each one wants its own particular parameters of interest to be monitored. It will never be possible to satisfy the needs of all the users, so it will always be necessary to decide which data, for which users, can be generated by a general monitoring program.

This document proposes to use in-house personnel for monitoring purposes and spend no more than about 2 percent of the budget of the protected areas system on monitoring equipment and external services. The salary value of fieldstaff for monitoring and the monitoring equipment together would make up about 20 percent of the total budget of the protected areas administration. In-house data should primarily be complimented by external data collection obtained from collaboration programmes and on the condition that data be made publicly available ultimately within a year of collection. The ecosystem-and-protected-area monitoring database is publicly available and allows storage of ecological (both terrestrial and aquatic), environmental and land-use data. By its primary focus on ranger-based monitoring, the method provides a very rapid-response system for some of the most devastating and immediate threats, like illegal deforestation, burning and poaching.

**ON SEMI-ANTHROPOGENOUS ECOSYSTEMS AND CULTURAL LANDSCAPES**

With regard to semi-anthropogenic ecosystems and cultural landscapes, particularly in temperate and boreal Eurasia different management approaches will be required to deal with partially restoration measures and management activities to conserve the effects of land-use practices that originated the characteristics of those ecological conditions. Such management practices often require substantial research and experimentation.

Under those conditions it is often not possible to acquire sufficiently large and continuous ecosystems in protected areas. In such cases one may often have to resort to different approach in which certain management practices to be applied to entire landscapes through coordination of management authorities and private land-owners.

## WELL-INTENDED STEP ON A LONG ROAD TOWARDS RATIONAL CONSERVATION MEASURES

In absence of more than mankind's fragmentary knowledge about biodiversity, this document has made an attempt to systematically reason how to meet the "minimum biodiversity conservation needs" for developing countries. It has heavily built upon universally accepted ecological mathematical models and theories, thereby making many principles useful for partial consideration in many boreal and austral countries as well. But any approach built on models should be applied with great caution. "Mathematical models serve as useful vehicles for thought" (Soulé 1987) and contain many simplifications and assumptions. The document does not pretend to present the sublime solution, but rather to offer a well-intended step on a long road towards systematically reasoned rational conservation measures. Many suggested concepts and ideas need testing and further development, so that bit by bit, humanity may succeed to maintain at least a part of all those wonderful treasures that together form life on earth. As we learn through the process of both trial and error and research, new lessons will become available, which we will post them on the WICE webpage: http://www.birdlist.org/nature_management/national_parks/national_parks_systems_development.htm

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## ANNEX I: RELEVANT TERMS DEFINED IN THE CBD[49]

"Biological diversity" means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.

"Biological resources" includes genetic resources, organisms or parts thereof, populations, or any other biotic component of ecosystems with actual or potential use or value for humanity.

"Ecosystem" means a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit.

"*Ex-situ* conservation" means the conservation of components of biological diversity outside their natural habitats.

"Habitat[50]" means the place or type of site where an organism or population naturally occurs.
"In-situ conditions" means conditions where genetic resources exist within ecosystems and natural habitats, and, in the case of domesticated or cultivated species, in the surroundings where they have developed their distinctive properties.

"*In-situ* conservation" means the conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings and, in the case of domesticated or cultivated species, in the surroundings where they have developed their distinctive properties.

[49] A list of definitions of technical terms for all documents related to this study is presented in Ecosystems and Protected Areas Monitoring Database Manual, (Vreugdenhil 2003).

[50] Often authors mix the meaning of the terms ecosystem and habitat, with habitat the suitable space for the population(s) of a single species. In this document, an attempt has been made to be very consistent in the distinction of the different meanings, and in the case of citations of inappropriate use, a footnote has been placed.

# ABOUT THE TASK FORCE

**Dr. Ir. Daan Vreugdenhil**, director of Conservation & Environment, has worked for 30 years in planning and management of natural resources of temperate and tropical terrestrial and aquatic environments. He graduated (cum laude) from Wageningen University in both vegetation and animal ecology and natural resources management. He started his career as project officer of the IYF, preparing the youth contribution to the **European Conservation Year 1970**. His tropical career started with a position as a resources management officer with FAO, with projects in Africa and South America. After return to the Netherlands, he became senior administrator with the Netherlands' Ministry of Works and Water, **Rijkswaterstaat**, where he was responsible for three different integrated programmes involving budgetary management of Euro 300,000,000 per year. In 1990 he returned to the international sphere as Chief of the Natural Resources Management Unit at **DHV-Consultants**, for which he developed and lead projects in Eastern Europe, Asia and Costa Rica. In 1992 he joined the **Inter American Development Bank** as an environmental specialist. In 1995 he became director of the **World Institute for Conservation and Environment**, **WICE** an independent thinktank and advisory institute. His work and travels have taken him to more than 70 countries of the world, in many of which he has been involved in some kind of advisory task. His life-time passion for national parks conservation culminated in coordinating this **task force of independent conservationist/scientists** whose joint life-time experience and expertise is reflected in the current document.

**Prof. Dr. John Terborgh** is Professor of Environmental Science and Botany and co-director of the Center for Tropical Conservation at Duke University, in Durban, North Carolina. He is one of the driving forces of the Wildlands Project, a far-reaching effort by scientists and activists to develop better ways of protecting nature, wilderness and biodiversity with the ultimate goal to establish an effective network of nature reserves through North America. He has carried out research in both tropical and temperate climate conditions, particularly in Manu National Park in Peru.

**Prof.Dr. A.M. Cleef**, teaches Actuo-ecologie at Amsterdam University and Tropical Vegetation Ecology and mapping at Wageningen University. For almost four decades, he has conducted vegetation and paleo-ecological research in the Andes and the mountain ranges of Central America and the reputation of his life-time involvement in the ECOANDES research project has made him an international recognised authority in tropical vegetation ecology.

**Dr. Maxim Sinitsyn** graduated from the Moscow State University as a Geographer (Zoo-geography and -ecology, Biogeography) and later received his Ph.D. at the Institute of Ecology and Evolution of the Russian Academy of Sciences, where he has been working as a staff scientist. Last year he became the Managing Director of the International Forest Institute, in Moscow. His specific area of research is the design of protected nature areas, wildlife and forest ecosystems sustainable management and mammal ecology. Over the past decade, he managed several international projects in different eco-regions including arctic territories, boreal forests and wetlands.

**Dr. Gerard C. Boere** graduated (cum laude) in 1971, at the Free University in Amsterdam in zoo-geography, bird migration and palaeontology. His PhD (1977) was on the international importance of the Dutch Wadden Sea for migratory Arctic breeding waders. As Head Flora and Fauna Conservation of the National Forest Service from 1977-1987 he was involved in almost every conservation issue in the Netherlands; in this function he e.g. prepared the reintroduction of the Beaver into the Netherlands. Since 1987 he works for the International Biodiversity Conservation Division of the Dutch Ministry of Agriculture, Nature and Food Quality in which capacity he was Head of the Dutch delegation to the Ramsar and Bonn Conventions. He developed e.g. the African Eurasian Migratory Waterbird Agreement and coordinated for 10 years the bilateral co-operation with the Russian federation e.g. on Arctic conservation and was and is active in many important international positions. He is presently seconded by the Dutch Government to Wetlands International. Throughout he has extensively dealt with the problems of the establishment and management of protected areas and protected area networks. In 2000 he was Knighted by Queen Beatrix and become an Officer in the Order of Orange Nassau; he also received the WWF International Award for Conservation Merit and the Golden Medal (as the first foreigner ever) from the Russian Conservation community".

**Ingeniero Victor Leonel Archaga** has a degree in tropical forestry and has served twice as director of the Protected Areas department of the Honduran Forest Service during which periods he was intensively involved in the conceptualisation and excecution of protected areas system analysis and monitoring programme development. He is currently director of the World Bank/UNDP Honduras protected areas project PPROBAP and is one of the most renowned conservationists in Central America.

**Prof. Dr. Herbert H.T. Prins** is professor in Tropical Nature Conservation and Vertebrate Ecology at Wageningen University, the Netherlands, since 1991. He has represented The Netherlands and the European Union at meetings of the Convention on Biological Diversity, is board member of “Natuurmonumenten”, the Dutch equivalent of the Nature Conservancy and other conservation organisations. He is member of the IUCN Species Survival Commission, Netherlands Committee IUCN, Member IUCN Committee on Ecosystem Management, IUCN Asian Cattle specialist group, and the Machakos Wildlife Forum, Kenya. He has conducted research and consultancies in Indonesia, Kenya, Tanzania, Zambia, Mozambique, and Canada. He is Officer in the Order of the Golden Ark.

## IUCN,

## The World Conservation Union

Founded in 1948, The World Conservation Union brings together States, government agencies and a diverse range of non-governmental organizations in a unique world partnership: over 935 members in all, spread across some 138 countries.

As a Union, IUCN seeks to influence, encourage and assist societies throughout the world to conserve the integrity and diversity of nature and to ensure that any use of natural resources is equitable and ecologically sustainable. The World Conservation Union builds on the strengths of its members, networks and partners to enhance their capacity and to support global alliances to safeguard natural resources at local, regional and global levels.

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## WICE

### World Institute For Conservation And Environment

WICE has been founded in the Netherlands in 1989. Its mission is to initiate, develop, promote and actively participate in activities that contribute to the conservation of nature and the improvement of the environment. WICE is a highly specialized biodiversity conservation planning and management institution that works at methods to conserve biodiversity efficiently, develop user-friendly tools and management applications and promote self-financing mechanisms for protected areas systems. It is owner of http://birdlist.org , a highly informative site about conservation of nature, including birds and mammals and offers many documents about conservation for downloading.

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