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Biological Diversity: Global Conservation Needs and Costs*

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BIODIVERSITY: GLOBAL CONSERVATION NEEDS AND COSTS

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A Case Study Prepared for
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1 INTRODUCTION

1.1 Global Concerns

The Ad-Hoc Working Group of Experts on Biological Diversity of the United Nations Environment Programme [UNEP] met in Geneva on 19-23 February 1990, in connection with its work to prepare a legal instrument or mechanism on the conservation of biological diversity for the planet [UNEP 1990]. It agreed on the following areas representing basic conservation needs, that would lead to measures of implementation and funding through the adoption of the new international legal instrument:

[1] **Survey, inventory, identification and authentication** of biological diversity with reference to rich and threatened areas, conservation technologies and techniques, and to sustainable use technologies and techniques;

[2] **Technical assistance and cooperation** for research, training and education, public awareness campaigns, surveys and inventories, etc. on biological diversity, in particular:

* **Biodiversity Research**: surveys and inventories of species, their ecology and natural history, their systematics and biogeography, and their ethnobiology;

* **Biotic Depositories**: establishment, maintenance, use and servicing of <u>ex-situ</u> and <u>in-situ</u> depositories of biological diversity;

* **Socio-Economic Research**: assessing the benefits and outputs derived from the conservation of biological diversity;

* **Education**: educating senior decision-makers on the importance of biological diversity, and the benefits lost when biodiversity is harmed;

* **Technical Training**: competence in the use of available technologies for the collection, identification, maintenance, monitoring and use of biological diversity;

* **Rights of Indigenous Peoples:** recognition of the rights of indigenous peoples to benefit from their highly practical knowledge of local organisms, incorporating traditional uses of local habitats and ecosystems;

[3] **Management strategies and plans** for conserving biological diversity with particular reference to rich areas, highly endemic areas, threatened areas, areal restoration and recovery, coordination of various conservation activities, networking of protected areas, and the development of national conservation strategies;

[4] **Regular monitoring** of the status of the world's biological diversity;

[5] **Coordination of conservation management strategies and plans** with sustainable development policies;

[6] **Priority conservation projects;**

[7] **Needs of existing international legal instruments** on biological diversity; and

[8] **Transfer of technology.**

Although biological diversity is now viewed as an economically valuable natural resource, the Group noted the considerable difficulties in adequately assessing the total economic value of the benefits of its conservation. The Working Group therefore identified among others the need for a case study on meaningful costing of global conservation needs. These basic conservation needs could be envisaged within the framework of a global strategy for conserving biological strategy.

1.2 Terms of Reference

This case study on the needs and costs of a global strategy for conserving biological diversity was commissioned on the basis of areas of basic conservation needs identified by the Ad-Hoc Working Group of Experts on Biological Diversity [UNEP 1990; see above]. It was given the following terms of reference:

[1] To assess the **cost of a global strategy** for conserving biological diversity over the next 10-20 years;

[2] To itemise separately **each specific cost element** in the strategy for conserving biological diversity in terms of capital costs, operating costs, one-time investment, recurring expenditure, etc.:

2.1 Formation of a **consensus on international priorities** for maintaining biodiversity;

2.2 Provision of a framework for detailed **Regional Action Plans** to stem the loss of biodiversity;

2.3 Realization of opportunities to use the Regional Action Plans to **benefit local and indigenous populations**;

2.4 Development of an **Emergency Action Plan for Protected Areas** for regions that require special attention, and for new Protected Areas needed in the regions that scientists agree have the greatest biodiversity value;

2.5 **Research into the identification, clarification, promotion and sustainable use** of tropical biological resources outside the main band of species now exploited;

2.6 **Research into the ways in which indigenous people harvest useful substances** from tropical wild lands on a sustainable basis; and

2.7 **Cost of obtaining patent protection for new medicines and other chemicals** derived from tropical species in order to overcome the private sector's reluctance to spend money on research in this area.

[3] To present **assumptions and methodology used** in calculating these costs to enable assessment of its reliability;

[4] To consider costs incurred as a result of **delaying development and growth**, and any other indirect costs;

[5] To identify which of these costs can be included for **additional finances or support**, and which should be met locally by governments.

This report on the case study attempts to address these terms of reference, in particular the needs and costs of a global strategy for conserving biological diversity based on the areas identified by the Ad-Hoc Working Group of Experts on Biological Diversity of the United Nations Environment Programme. It follows the outline of these terms of reference.

1.3 Rationale for Conserving Biological Diversity

"**Biological diversity** refers to the variety and variability among living organisms and the ecological complexes in which they occur. **Diversity** can be defined as the number of different items and their relative frequency. For biological diversity, these items are organized at many levels, ranging from complete ecosystems to the chemical structures that are the molecular basis of heredity. Thus, the term encompasses different ecosystems, species, genes, and their relative abundance" [OTA 1987].

Biological diversity constitutes the common heritage of humankind and the capital stock of this planet, the renewable rate of which is the "interest" supporting life especially human life and carrying capacity. It therefore commands a sense of common responsibility for conservation, even though legally it is not commonly owned by all humankind as a property. Biological diversity has never been constant in the history of planet Earth. It has experienced rapid extinction periods at several points in geological history followed by "recovery" in directions that were basically unpredictable and that involved evolutionary processes that promoted greater control and independence in relation to environmental fluctuations. The last major extinction of biological diversity occurred during the Cretaceous Period, about 65 million years ago, when birds and mammals were particularly affected. Biological diversity is currently being lost at an unprecedented rate due to anthropogenic causes. For the first time in geological history, the expansion of human populations and their life-support systems [including technologies], are especially affecting the tropics and the marine environment which contain more than 50% of the species diversity on this planet, and isolated mountains and oceanic islands which have a high degree of endemism. This loss is serious for it potentially threatens human advancement and the sustainability of economic livelihood and prosperity which largely depend on the utilization of biological resources and ecological processes, and take advantage of the properties of plants, animals, fungi and microorganisms for food, clothing, medicine, various services, shelter and industrial materials. In spite of an understanding of this reciprocal linkage between development and environment, however, only a small fraction [2-5%] of biological diversity has been surveyed, authenticated and widely used over the past 300 years. For example, out of an estimated total of 5-80 million species on planet Earth, only 1.4 million have been authenticated and given scientific names [Wilson 1988]. Similarly, habitats and ecosystems in the boreal and terrestrial zones have been studied intensively in comparison to tropical and marine environments.

Vast areas of biological diversity are largely unknown, therefore, particularly in the tropics and the marine environment, and among insects, other invertebrates and microorganisms. Yet, 50% of species diversity occurs in closed tropical forests which are being destroyed at the rate of 5-10% every 10 years, causing the extinction of about 100 species per day. The current loss of biological diversity includes that which is known and unknown [or still undiscovered]. The causes of this loss are both direct and indirect:

[1] **Habitat and ecosystem destruction** in the process of spatial conversion for economic uses [e.g. large-scale monoculture plantations], resulting in the extinction of genetic and species diversity;

[2] **Habitat and ecosystem fragmentation** in the process of spatial transformation for economic uses [e.g. industrial complexes, small-holdings], resulting in the reduction of genetic and species variability;

[3] **Species overexploitation** for trade and economic use [e.g. ivory trade, trawl-fishing], resulting in loss of species and genetic variability and destruction of habitat and ecosystem diversity;

[4] **Disease epidemics and predation pressures** in simplified and attenuated ecosystems that were previously not known, resulting in reduction of species, genetic and habitat and ecosystem variability;

[5] **Species displacement** by the invasion of exotic species or virile mutants, resulting in loss of species and genetic diversity and variability, and in reduction of habitat and ecosystem diversity; and

[6] **Pollution** [e.g. acid rain, eutrophication] of habitats and ecosystems, resulting in loss of species and genetic diversity, and reduction of habitat and ecosystem variability.

Although there is no possibility of surveying and authenticating all the biological diversity on planet Earth in view of the rate of destruction of tropical forests [1-5% per decade], isolated habitats and of the marine environment, it may be possible to conserve 10-20% and significant proportions of it within the next 10-20 years by allocating additional resources to strategic elements of a coordinated programme. This has been recognised by the Ad-Hoc Working Group of Experts on Biological Diversity of the United Nations Environment Programme [UNEP 1988a, b & c].

1.4 Materials and Methods

Materials for this case study on the global needs and costs of conserving biological diversity were obtained from bilateral and multilateral organizations, non-governmental international organizations, governmental organizations and individual experts mainly in Europe and North America. It involved brief field visits to Washington, New York, Paris, Geneva and Rome to meet with institutions and experts, discuss with them the issues that were raised and to obtain from them appropriate [even draft] documentation wherever possible. In spite of time constraints, the following organizations and their staff provided useful information generously:

* The Chilean National Union for the Environment [PNUMA],
* The Commission of the European Communities [ECE],
* The Commonwealth Science Council [CSC],
* The Conservation International Foundation [CI],
* The Consultative Group on Biological Diversity [CGBD], at the Rockefeller Brothers Fund,
* The Consultative Group on International Agricultural Research [CGIAR],
* The Convention on the International Trade on Endangered Species [CITES] Bureau,

* The Convention on Migratory Species [CMS] Bureau,
* The Council of Europe [CE],
* The Dag Hammarskjold Foundation,
* The Danish National Forest and Nature Agency,
* The Ethnobiological Institute for Amazonia [INEA],
* The Finnish Ministry of the Environment,
* The Food and Agriculture Organization of the United Nations [FAO],
* The Inter-American Development Bank [IADB],
* The International Association for Ecology [INTECOL],
* The International Board on Plant Genetic Resources [IBPGR],
* The International Council of Scientific Unions [ICSU],
* The International Fund for Agricultural Development [IFAD],
* The International Institute for Tropical Agriculture [IITA],
* The International Union of Biological Sciences [IUBS],
* The International Union for the Protection of New Varieties of Plants [UPOV].
* The National Academy of Sciences of the United States [NAS],
* The Natural Resources Defence Council [NRDC],
* The Oxford Forestry Institute [OFI],
* The Ramsar Convention Bureau,
* The Royal Botanic Gardens Kew,
* The Royal Society of London,
* The Smithsonian Institution or the United States Museum of Natural History,
* The United Nations Centre for Science and Technology for Development [UNCSTD],
* The United Nations Development Programme [UNDP],
* The United Nations Educational Scientific and Cultural Organization [UNESCO],
* The United Nations Environment Programme [UNEP],
* The United States Agency for International Development [USAID],
* The U.S.S.R. Nature Conservation and Environmental Protection Institute,
* The World Bank or the International Bank for Reconstruction and Development [IBRD],
* The World Conservation Monitoring Centre [WCMC],
* The World Conservation Union or the International Union for Conservation of Nature and Natural Resources [IUCN],
* The World Heritage Convention Bureau,
* The World Resources Institute [WRI],
* The World Wide Fund for Nature Conservation [WWF - UK],
* The World Wide Fund for Nature Conservation [WWF - International], and
* The World Wildlife Fund [US].

Individuals in these and other organizations who were helpful in providing information are acknowledged in Annex.

1.5 Constraints

The material received and information obtained for this case study was too patchy to address the terms of reference in full, especially the detailed costs of a global strategy and programme for conserving biological diversity over the next 10-20 years. It is doubtful if such a cost estimate can be realised meaningfully without fully consulting countries in the tropics and their trading partners, all maritime countries and a variety of experts knowledgeable about biological diversity, resource transformations and technological innovations, in view of the paradox underlying international trade and development. Development investments affect biological diversity by transforming natural resources [or the "outer" limits of the biosphere], and concurrently prescribe the limits for realising the aspirations of all people affected and involved for a more equitable and a better quality of life [or the "inner" limits of human advancement]. Although the tropical and marine environments possess much of the global heritage of biological diversity which is currently threatened by population and economic growth pressures, the countries in these environments are essentially developing and are acutely short of financial resources, training facilities and technical expertise for managing this natural global heritage even for their own welfare and advancement. These countries are thus constrained in making effective use of any new international approach or fund for development, that may became available for the conservation of biological diversity on a global scale.

2 NEEDS AND COSTS OF A GLOBAL STRATEGY

The Ad-Hoc Working Group of Experts on Biological Diversity of the United Nations Environment Programme decided that existing conservation conventions and other relevant international programmes were essentially sectoral and could not adequately meet the aim of conserving biological diversity at the global level [UNEP 1988a, b & c]. It further decided on areas of basic global needs [see above] that should contribute towards the framework of a global strategy for conserving biological diversity, which would build on current conventions and programmes [UNEP 1990]. An overall assessment of the cost of a global strategy for conserving biological diversity over the next 10-20 years must assume consultation with experts, countries and regions, and with ongoing programmes of global significance. However, in the limited time available for this case study, it was not possible to conduct these full consultations. A variety of inter-governmental and non-governmental programmes, together with the framework of a global strategy [see Section 3 below], were used to arrive at a magnitude of the cost estimates for such a global strategy for conserving biological diversity.

Implementation of a global strategy for conserving biological diversity, and promoting the sustainable use of natural resources in the future, demands:

* An **understanding of the pace and unpredictable pattern of** technological innovations in transforming natural resources into useful products and commodities, and thereby impacting the environment, in response to changing human perceptions of sustainable economic livelihoods and needs concurrently at local and global levels;

* Reliable information for resource development and environmental management;

* Integrative strategies for conserving biological diversity with cultural development; and

* Regional and global coordination of plans and programmes which promote local adaptation and implementation.

There is very little new information being generated currently about the nature of biological diversity in the tropics and the marine environment where much of it resides and is of global significance, and about its management. Most of this information originates from research investments by the non-governmental sector; and 90% of research [and presumably management] efforts on biological diversity are concentrated in the polar and not the tropical zones. This skewed distribution of information for the conservation of biological diversity is exacerbated by two further factors: [1] computerised collations on conservation issues which often appear to provide "global" figures about biological diversity without exhibiting an in-depth appreciation of the complexities of the issues concerned; and [2] the trend in many cases to aggregate the traditional sectors of forestry, agriculture and fisheries under "biological diversity".

It is difficult to estimate the magnitude of additional funds required for a global strategy for conserving biological diversity due to the paucity of information available, and shortcomings in its clarity and reliability. Even though nation states and development assistance agencies already spend billions US$ annually for nature protection and environmental management, a global conservation strategy will require additional funds in view of the gaps in current conservation programmes. There is a shortfall of funds in most developing countries in the tropics for conserving biological diversity. For example, the three countries of East African, Kenya, Tanzania and Uganda, have a budget of US$11 million per annum for administering wildlife protection when their needs amount to US$84 million per annum; and an administrative budget of US$1.1 million per year in Tanzania generates revenue earnings of US$4.5 million per annum. The official development assistance on a worldwide basis exceeds US$40 billion per annum and very little of it concerns the conservation of biological diversity. The World Resources Institute has estimated the need for additional funds amounting to US$20-50 billion per year for a global strategy for conserving biological diversity [WRI 1989]; the World Wide Fund for Nature Conservation [UK] has estimated the need for an additional US$100 million per year; and the Union of the Soviet Socialist Republics has estimated its additional needs in terms of US$1.00 billion per year. Professor David Pearce [pers. comm.] has estimated the need for a transfer of US$3.2 billion per annum to conserve tropical forests based on the existence value of tropical species and habitats in the rich industrialised countries. While there is considerable variation in the figures and uncertainty about their basis, additional funds **at least of the order of hundreds of millions to units of billions US$ per year** appear necessary for surveys and inventories, identification and authentication, technical assistance and cooperation in research, curation, education and training and traditional uses, management strategies and plans, monitoring and conservation coordination, priority projects and for the transfer of technology, for conserving 10-20% of biological diversity especially in tropical and marine environments over the next 10-20 years. The availability of any additional funds will have to be phased gradually to match their absorptive capacity especially in developing countries in the tropics.

3 ELEMENTS OF A GLOBAL STRATEGY

On the basis of global conservation needs identified by the Ad-Hoc Working Group of Experts on Biological Diversity of the United Nations Programme, the following specific elements should be identified in a global strategy for conserving biological diversity over the next 10-20 years:

[A] Formation of a consensus on international priorities for maintaining biodiversity;

[B] Provision of a framework for detailed regional action plans to stem the loss of biodiversity;

[C] Realization of opportunities to use the Regional Action Plans to benefit local and indigenous populations;

[D] Development of an Emergency Action Plan for Protected Areas for regions that require special attention, and for new protected areas needed in regions that scientists agree have the greatest biodiversity value;

[E] Research into the identification, clarification, promotion and sustainable use of tropical biological resources outside the main band of species now exploited;

[F] Research into the ways in which indigenous people harvest useful substances from tropical wild lands on a sustainable basis; and

[G] Cost of obtaining patent protection for new medicines and other chemicals derived from tropical species in order to overcome the private sector's reluctance to spend money on research in this area.

Each of these elements of a potential global strategy are discussed separately.

3.1 Consensus on International Priorities

Formation of a consensus on international priorities for maintaining biological diversity relies on the availability of reliable information on genetic, species and habitat and ecosystems diversity nationally as well as regionally. It will require regional and international meetings and consultations to coordinate conservation action; and will depend on a national and regional capability for monitoring the status of conservation of biological diversity. International conservation priorities should include issues pertaining to large areas with high biological diversity [e.g. tropical forests, coral reefs] or with low biological diversity [e.g. tundra, deserts, open sea], besides small areas with high endemism [e.g. oceanic islands, isolated mountains and lakes], especially in the tropics and the marine environments. There will be the need to assess regional and international priorities for conserving taxa, areas, depositories, repositories, technology transfer and technical expertise. Consensus formation should be based on one or more of the following mechanisms: specialist consultations, broader technical consultations, governmental consultations, public awareness campaigns and consultations, and international advisory meetings. Although the costs of consensus formation are difficult to assess, they should require additional funds of about US$10 million per year in view of the cost of coordinating the International Biological Programme [IBP] at US$1-3 million per year and the costs of programme coordination of the World Conservation Union [IUCN] at US2-3 million per year.

3.2 Regional Action Plans

3.2.1 Introduction

There is a need to provide a framework for regional action plans to stem the loss of biological diversity especially in the tropics and the marine environment, by coordinating conservation strategies and plans with sustainable development policies. Regional action plans should relate to the international priorities for conserving biological diversity; and should generate new information on conservation and development by promoting surveys and inventories, the function of depositories and repositories, identification and authentication, the study of key ecological processes, the integrated management of technology transfer, and by promoting the training of appropriate professional expertise. These plans can only be developed in consultation with countries in a region, and by examining the gaps in regional action plans already in existence. The information collected was inadequate to permit assessment of such gaps.

3.2.2 Existing Regional Action Plans

A variety of regional action plans already exist under the sponsorship of international intergovernmental and non-governmental organizations; and promote the conservation of one or more aspects of biological diversity. These are complemented by regional actions of bilateral development assistance agencies. It has not been possible to survey the range of regional plans in operation. The following selection is an illustrative list:

* **The World Commission on Plant Genetic Resources** under the auspices of the FAO.UN has a defined programme on the conservation of plant species of food, agriculture and forestry potential. It is executed through a network of national institutions with regional collaboration in the collection, storage or planting and testing of material. The programme is reviewed every five years by expert panels.

* **The International Board on Plant Genetic Resources** has a coordinated programme at its regional international centres for agricultural research, to collect, store and test plant material of the main food crops. Each centre is dedicated to a specific crop or to crops of a region; and field tests include farming systems trials in a region.

* **The Tropical Forestry Action Plan** is a global framework for action in tropical forestry. It´s coordinating unit is located at the Food and Agriculture Organization of UN. It involves >5-10% of the overseas development assistance [ODA], and in 1986 consumed US$515 million for investment and $393 million for technical assistance [Table 1] [FAO 1987]. Bilateral and multilateral development assistance agencies contribute equally to this Plan. Conservation of tropical forest ecosystems is one of the five priority areas of this plan, and it involves approaches for:

  * Sustainable use of the forest for the production of wood, food, fodder and other non-wood products;

  * A series of protected areas;

  * Maintenance of intraspecific variation of species of actual or potential socioeconomic importance and other species;

  * National parks and protected areas within the pattern of land use of benefit to local people;

* Closer linkages between biological diversity conservation policies and recovery of natural vegetation for watershed protection;

* Assembly of information on germplasm collection;

* Public awareness about biological diversity conservation; and

* Staff training.

Only a small proportion of TFAP funds has been used for ecosystems conservation [5%] and watershed management [30%], with most allocated to Africa [42%] and the Asia-Pacific [41%] regions [FAO 1987]. However, the TFAP has generated multiplier effects mainly in the form of bilateral cooperative [332/593 cooperative actions]. The plan aimed to raise US$8 billion over five years, but does not appear to have reached its target.

* **The Man and Biosphere [MAB] Programme** of the United Nations Educational Scientific and Cultural Organization promotes research, training and development on various aspects of biological diversity conservation. It has a representative coverage of ecosystems on a global scale known as Biosphere Reserves. Its programmes are coordinated regionally, but its assured funds are only about US$1.1 per annum.

* **UNESCO's Mangrove Programme** also promotes research, training and development on various aspects of biodiversity conservation. It also is coordinated regionally.

* **The Intergovernmental Oceanographic Commission's** regional programmes, like that for the Western Pacific, promotes research, training and development of marine resources conservation near-shore and off-shore. It is regionally coordinated.

* **The Regional Seas Programme** of the United Nations Environment Programme promotes research, training and development of marine conservation and environmental protection. It is coordinated regionally.

* **National Conservation Strategies** under the auspices of the International Union for Conservation of Nature and Natural Resources have been restricted hitherto. There are moves to promote them on a regional basis in the near future.

3.2.3 Effective Coordination

Coordination of the various regional action plans concerning the conservation of biological diversity is carried out to some extent by the Ecosystems Conservation Group [ECG]. This Group is currently limited in membership, and consists of the Food and

Agriculture Organization of the UN [FAO], the United Nations Educational Scientific and Cultural Organization [UNESCO], the United Nations Environment Programme [UNEP] and the World Conservation Union [IUCN]. **The effectiveness of these regional action plans and other emerging programmes should be assessed in terms of:**

[1] Promoting research, training and development of technologies for conserving biological diversity *in-situ* and *ex-situ*;

[2] Focusing on plants, microorganisms and terrestrial and aquatic invertebrates for species conservation, and on tropical and marine environments for habitat and ecosystem conservation;

[3] Catalysing national programmes for biological diversity conservation;

[4] Promoting sustainable use of resources, and the development of appropriate tools for integrated assessment;

[5] Training local expertise in a variety of conservation technologies; and

[6] Establishing and maintaining networks of cooperating individuals and institutions on different facets of biodiversity conservation.

Networks of individuals and institutions cooperating regionally or internationally are an inexpensive and efficient mechanism for promoting regional action and calibration on the conservation of biological diversity. Their success however depends on:

* A clear definition of the problem for conserving biological diversity that is common to the region;

* Identification of a "lead" centre capable of providing leadership on the problem defined, with the prospect of rotating this role among participants;

* Identification of network participants for their expertise and strong commitment to make a contribution;

* Encouraging active participation and providing resources or support as may be necessary; and

* Promoting communication and feed-back, including the exchange of material and results.

Regional action plans should be able to promote surveys and inventories, identification and authentication services; technical assistance and cooperation for biological diversity research, depositories and repositories, socio-economic research, education and training, management strategies and plans, and monitoring; and priority projects to demonstrate conservation and sustainable use technologies, and in different biome types.

3.2.4 Surveys and Inventories

Surveys and inventories of genetic, species and habitat and ecosystems diversity have been patchy and inadequate due largely to the strategic and limited investments of metropolitan or industrialised countries, and to the scarcity of resources and technical expertise in developing countries especially in the tropics. Nevertheless, commercial institutions have been involved in surveys and inventories having a direct market interest, governmental and inter-governmental institutions in those of importance to national security especially in natural resources and land and water use, and universities and private institutions have been involved in those usually not perceived important for strategic development. There has been a hiatus of 50-80 years in international surveys and inventories since the early part of this century due to the emergence of independent nation states and transitions towards global governance. However, such surveys have been stimulated recently through international scientific programmes such as the International Biological Programme [IBP], the Man and Biosphere [MAB] Programme and the International Geosphere-Biosphere Programme [IGBP], and through the commercial search for alternative phyto-chemicals for industries.

Biological diversity of immediate importance to natural resources development [i.e. agriculture, fisheries and forestry] has been better surveyed than others. Similarly, unique species, habitats and ecosystems of touristic and recreational importance have been better surveyed than others. As a consequence, for example, only 2.5 million species or taxa have been surveyed especially over the past 300 years, out of an expected potential of 25 million species, although some estimates suggest 30-80 million species due to the predominance of insects in tropical forests and invertebrates in the seas [Wilson 1988]. The patchiness of these surveys can be illustrated by poor knowledge about microorganisms of which about 13% are known, but which perform important roles "bridging" the interfaces of the geosphere, biosphere and atmosphere [Hawksworth <u>in</u> di Castri and Younes 1990]; and by poor knowledge about insects and invertebrates, <10% of which are known.

Surveys and inventories of biological diversity have an essential geographic component. They are complete only when collecting or survey in a particular area ceases to yield any new information on varieties or forms. However, they are still yielding new varieties of genes, taxa and habitats and ecosystems particularly in tropical and marine environments which have been surveyed inadequately hitherto. In the Brazilian Amazon, for example, the rate of discovery of new taxa or species is 1-9% of determinations for plants [Campbell 1989]. It is likely to be much higher for invertebrates particularly insects which dominate tropical ecosystems, and for microorganisms and marine benthic species which have been poorly studied; and for other biogeographic regions which have been less well surveyed.

Table 1: Collection Density [D] [1981] of Herbarium Specimens and Rates of Botanical Inventory [N] in Tropical Countries/Regions

REGION/COUNTRY	D	N	REGION/COUNTRY	D	N
ASIA & AUSTRALIA			**AFRICA**		
China	50	21	Sierra Leone	50	43
Taiwan	534	0	Liberia	6	*
Philippines	42	5	Ivory Coast	7	*
Thailand	23	*	Ghana	48	58
Malaysia & Singapore	219	0	Benin & Togo	5	126
Brunei	123	0	Nigeria	14	175
Indonesia	86	18	Cameroun	10	65
Papua New Guinea	46	193	Gabon	1	618
Burma	5	676	Congo	9	*
India	107	0	Zaire	5	*
Sri Lanka	152	0	Central African R.	1	*
Australia	56	117	Angola	5	90
Pacific Islands	529	0	Uganda	7	*
			Kenya	64	27
SOUTH AMERICA			Tanzania	5	398
The Guianas	11	741	Madagascar	9	*
Venezuela	23	59			
Colombia	30	39	**CENTRAL AMERICA**		
Ecuador	21	70	Mexico	48	13
Peru	28	77	Belize	17	133
Bolivia	1	707	Guatemala	34	42
Brazil	25	59	El Salvador	268	0
			Honduras	136	0
CARIBBEAN			Nicaragua	22	34
West Indies Islands	261	0	Costa Rica	236	0
			Panama	44	12

N = No. of years required to reach a satisfactory collection density [D]; * = Infinity

SOURCE: Campbell [1989]

Various indices have been developed to gain an understanding of the adequacy of surveys and inventories. For example, a collection "density index" [No. of specimens deposited per 100 sq km] has been used as a measure of adequate sampling of an area; and an index of 100 has been designated arbitrarily to indicate that an area has been sufficiently sampled for plants in terms of specimens deposited in local herbaria [Table 1] [Campbell 1989]. Although this may be a low index for regions where many early and valuable specimens have been deposited in European and American collections in the course of the colonial history of many tropical countries, it is nevertheless useful in demonstrating that tropical Asia, Oceania, Central America and the Caribbean have been better surveyed for plants than tropical Australia, South

America and Africa. On the basis of such information, priority areas can be identified for future botanical explorations [Table 2] [Campbell 1989]. A similar situation probably prevails for the higher vertebrates and butterflies which have attracted the interests of naturalists. In contrast, microorganisms, lower plants, terrestrial and aquatic invertebrates particularly insects and the lower vertebrates have been less well surveyed. In view of differences in taxonomic specialisation, there is no concurrence among scientific experts on the priority areas for future survey of biological diversity.

Table 2: Areas of Highest Priority for Botanical Surveys

REGION/COUNTRIES	REGIONS/COUNTRIES
ASIA India: Nagaland Thailand: central plain, NW & W highlands Vietnam: NE and Danang-Hue Laos: southern Kampuchea: SW Philippines: Luzon mountains, Samar-Leyte limestones, Mindanao mountains, Mindoro and Palawan Borneo: mountains, islands, NW Sumatra: N and N islands, E, SE and S islands Sulawesi: N, central and SW Moluccas: New Guinea: mountains, lowlands and adjacent islands	**AFRICA** Sierra Leone: interior Liberia: interior Ivory Coast: Ghana: SW Nigeria: delta, E Cameroun: Zaire: Kenya: rift valley, E and mountains Tanzania: rift valley and mountains & plateaus Uganda: mountains Madagascar:
SOUTH AMERICA Venezuela: highlands Colombia: highlands, coasts Ecuador: highlands, coasts Peru: highlands, Amazon Bolivia: Amazon Brazil: Amazon, E coast	**CENTRAL AMERICA** Mexico: highlands, E coast Guatemala: highlands, S Peten Honduras: highlands, coasts Nicaragua: highlands, coasts Costa Rica: highlands Panama: highlands, coasts **CARIBBEAN** Dominican Rep.: highlands

SOURCE: Campbell [1989]

Genetic diversity has been poorly surveyed except for species of immediate economic importance. For example, out of 80,000 plant species which provide suitable food for humans, only 150 species have ever been cultivated on a large scale, and less than 20 species provide 90% of the world's food. It would be extremely difficult and expensive to survey genetic diversity in a comprehensive manner, and a selective approach must therefore be used.

Habitats and ecosystems have also been inadequately surveyed in the tropics and oceans in comparison to the temperate and boreal zones because of differential research capabilities and investments. Udvardy's [1975] classification provides a generalised picture of tropical biomes and ecosystem types. It is not applicable to the marine environment; and therefore needs to be reexamined and refined by the application of modern advances in community ecology to the understanding of biotopes and ecosystem types in the tropics and by the role of ocean currents in dispersing larval forms in the marine environment.

In view of the foregoing, **a state-of-the-art review of biological diversity is therefore urgently needed especially for the tropics and the marine environment, and for microorganisms, invertebrates and lower vertebrates**. It will enable planning of future surveys, identification of their location or concentration and monitoring of concerted international action.

The technology used for surveys and inventories of biological diversity have not changed significantly in being [a] labour-intensive and [b] dependent on specialised technical expertise. Technological advances of importance have occurred in areas of commercial interest such as genetic "fingerprinting" for assessing genetic diversity, electron and interference microscopy for species diversity, and remote-sensing for assessing habitat and ecosystems diversity related to functional criteria. There is a need for promoting the wider application of these advances to surveys and inventories of biological diversity.

It is difficult to cost future surveys and inventories of biological diversity at this stage. Many of the costs are hidden in the voluntary and dedicated efforts of a small proportion of individuals. However, on the basis of taxonomic uncertainty, at least a 6-10 fold increase in resources is needed to obtain a reasonable understanding of biological diversity in the tropics and the marine environment, in comparison to the resources expended over the past 250 years, particularly in view of its rapid extinction and destruction. For flowering plants, for example, additional funds amounting to US$33-66 million would be required to discover 10-20% more species respectively, based on a conservative unit cost of US$2,630 for the discovery of a new taxon in the tropics. If plants are only 10% of all the species determined thus far, then additional funds amounting to US$330-660 million would be needed to discover 10-20% more new taxa. This is a conservative estimate in comparison to the 6-10 fold more taxa estimated to occur on this planet, which could cost US$1-5 billion to survey and inventory. On the basis of an escalation in the magnitude of technology used, the costs for habitat and ecosystem surveys at one order of magnitude greater than species surveys could be US$10-50 billion; and the costs for genetic surveys at two orders of magnitude greater than species surveys could be US$100-500 billion. However, it is unrealistic to consider comprehensive surveys at this stage due to the rate of loss of biological diversity and to the limited absorptive capacity of additional large investments in tropical developing countries where this diversity is located, and where only 10% of the professional expertise of the industrialised countries can be found. It would be realistic to plan for an additional expenditure of 10-20% of the total estimated costs of surveys and inventories over the next 10-20 years in view of the rapid degradation of terrestrial and marine habitats in the tropics; and this could mean **an additional US$330-660 million for all taxa, US$1-5 billion for habitat and ecosystems surveys, and US10-50 billion for genetic surveys**. However, even this is somewhat unrealistic since surveys and inventories are usually undertaken in conjunction with other functions like authentication. **Assessment by local communities, provinces and countries of their priority needs for new knowledge is essential for successful surveys and inventories, and this has to be undertaken in relation to spatial areas, habitat and ecosystem types, taxonomic and species ranges, genetic variability, survey and use technologies, and technicians and expertise.** For example, the framework used by the United States of America when undertaking its survey on plant diversity needs in the early 1980s [Table 4] could be adapted for other target groups of species such as microorganisms, terrestrial and aquatic invertebrates and marine biota, and for tropical and marine habitats and ecosystems, all of which are poorly known.

3.2.5 Identification and Authentication

Not all the biological diversity surveyed has been identified and authenticated. If one examines the authentication of species diversity, for example, only 1.435 million taxa have been identified and authenticated in comparison to the 2.5 million surveyed and the estimated total of about 25 million taxa [Wilson 1988; McNeely, Miller, Reid, Mittermeier and Werner 1990]. Much of this is due to inadequate investments in taxonomy, the shortage of expertise in the tropics especially on microbia, invertebrates and marine biota, and to the remote location of the major reference collections in the temperate zone countries. On the basis of an estimated total population of 1,500 taxonomists in 1980, there appears a need for about 7,500 more taxonomists [McNeely et al. 1990]. Training such expertise is time-consuming requiring 3-5 years to gain proficiency after a basic degree, is expensive requiring at least US$15,000 per person per year, and is demanding on supervision and apprenticeship. Inadequacies in basic taxonomic training at this level in authentication and verification can seriously jeopardise other forms of research and resource transformations. Given the disproportionate prevalence of scientific expertise in the industrialised temperate zone countries, it is unlikely that developing countries in the tropics could provide all the expertise required for authenticating their biological diversity heritage. Information was not available to assess the needs for authenticating genetic and habitat and ecosystem diversity; although it would be more expensive to train expertise in these areas by about two-fold in comparison to species diversity due to expensive laboratory or field equipment required. Institutions with expertise for training in these areas are relatively scarce in tropical developing countries.

Holdridge [1967] has developed a life-zone system for classifying terrestrial habitats and ecosystems. This needs to be refined further with respect to species associations. A similar system is lacking for the marine environment especially for the open sea.

Table 3: Knowledge of Floras in 82 Tropical Countries

STATE OF KNOWLEDGE: / REALMS:	NATIONAL CHECK-LIST OF PLANTS	FLORA IN PREPARATION	FLORA PREPARATION VERY ADVANCED	IUCN LIST OF THREATENED SPECIES AVAILABLE	OTHER LISTS OF
AFROTROPICAL	7	19	16	7	1
NEOTROPICAL	-	10	1	1	3
INDOMALAYAN	1	11	-	1	-
AUSTRALIAN	-	1	-	1	1
OCEANIAN	-	-	-	-	-
TOTAL [82]	8	41	17	10	5

SOURCE: Lucas and Synge [1978].

As a consequence, the knowledge about classification of biological diversity is very patchy. For example, tropical floras appear better known for Africa [Table 3] [Lucas and Synge 1978] even though they may have been inadequately surveyed [Table 1]; and it would take at least two decades to complete the floras under preparation. Countries could use the approach used by the United States of America when assessing its own knowledge and needs about plant diversity [Table 4], to determine their own needs for surveys, depositories and repositories, identification and authentication, understanding ecological processes, promoting R&D and technological innovation, and undertaking training and consultations. Each of these steps is expensive. For example, the maintenance of a living plant species <u>ex-situ</u> in a depository costs about US$500 per year; and such expenditures are difficult to access in budget allocations when financial resources are in scarce in developing countries. As a consequence, **assessment of**

needs for identifying and authenticating biological diversity in tropical and marine environments must relate especially to taxa and classification systems of importance to the local and international economy, to management and technological innovation, and of importance to the strategic training of specialists.

Table 4: Knowledge about Plant Species Diversity

CATEGORY:	I	II			III			IV			
PLANT GRP	1	2	3	4	5	6	7	8	9	10	11
IDENTIFICATION	H		H			H				NA	
ACQUISITION	NA		NA			M				H	
MAINTENANCE	Lx Hi		Lx Hi			Hx Hi				Hx Li	
EVALUATION	H		H			H				H	
ENHANCEMENT	NA		NA			L-M				H	
MONITOR GENETIC VULNERABILITY	NA		M			H				H	
INFORMATION MANAGEMENT & COMMUNICATION	H		H			H				H	
TRAINING	H		H			H				H	

PLANT GROUPS: 1 = Unclassified species, 2 = Named species, 3 = Distribution known, 4 = Synecology known, 5 = Usefulness primitive, 6 = Composition known, 7 = Exploited from the wild, 8 = Progenitors of cultivated species, 9 = Minor local crops, 10 = Minor extensive crops, 11 = Major crops

x = ex-situ, and i = in-situ

CATEGORIES: I = Species with essentially no information,
II = Species of known taxonomy, and general distribution and ecology,
III = Species not cultivated but with some useful potential,
IV = Cultivated species and their progenitors with local, regional or global economic importance.

SOURCE: DOS [1982].

3.2.6 Ecological Research

The ecological processes sustaining biological diversity are complex [Table 5] and have been poorly examined in tropical marine and terrestrial environments. This paucity of knowledge is due to taxonomic uncertainties, complex interactions at the photic [or canopy] and substrate [or benthic] zones, horizontal and vertical ecotonal linkages [e.g. land-water], a high degree of symbiosis, the dominance of biotic factors [e.g. predation and parasitism] in natural selection in contrast to abiotic factors in the polar and arid regions, difficulties in characterising patch dynamics, and to shortages in funding and of professional expertise. Most such studies have been undertaken by private and academic institutions, although some autecological studies have been pursued through inter-governmental organizations such as the World Commission on Plant Genetic Resources and the Tropical Forest Action Plan.

Understanding the ecological processes maintaining biological diversity is important for several reasons. For example, many chemical products produced by plants are generated in response to interactions with specific animals. Land-water ecotones, for example, are often characterised by higher species diversity than adjacent patches due to an optimal interaction between patch [or mosaic] size and edge effects [Naiman, Decamps and Fournier 1989]. This kind of knowledge has been used traditionally by farmers in the dyke-pond systems of southern China and in the home gardens of Mexico and Indonesia, for example, to saturate their planting systems with habitats and species to reduce the risk of any single crop failure, to recycle waste materials from one sub-system into another and to optimise biomass production per unit area of land and water. Transition zones are important, therefore; and an understanding of ecotone-biodiversity relationships is necessary for managing landscape mosaics. Species with an alternation of generations [e.g. insects, parasites] and mobile or migratory species [e.g. birds, fishes] complicate such relationships by using more than one ecotone or ecosystem in their life-cycle. There is a need to **assess the ecological processes important at the local, provincial and national levels for sustaining biological diversity in the tropical and marine environments in terms of key factors operational at each level and between levels, the role and nature of perturbations, the causes of high species diversity and endemism, and the causes of threat and extinction.**

It is difficult to estimate the cost of ecological research related to biodiversity since it would be determined by the nature and complexity of the problem. However, on the basis of the availability of US$0.5 million per annum to stimulate and coordinate research in each country, an initial sum of US$50 million could be needed per annum.

Table 5: Ecological Processes Sustaining Biological Diversity

[A] GENETIC DIVERSITY

1 Mutation: Random or Directed
2 Genetic Drift: Clinal variation, Isolation
3 Reproductive Systems: Sexual or Asexual [Fission, Parthenogenic, Vegetative]
4 Pollination or Fertilisation Systems: Mass Transfer [Wind, Thrips, Water Currents] or Selective [Bats and Bees, Moths and Butterflies, Internal or External]
5 Mating Systems: Random or Assortative [Phenotypic positive or negative, Genotypic positive]
6 Selection Pressure: Abiotic or Biotic [Predation, Parasitism]

[B] SPECIES DIVERSITY

1 Environmental Tolerance: Morbidity and Lethal Limits, Antagonistic and Synergistic Effects, "Edge" Effects
2 Niche: Size, Specialist or Generalist
3 Alternation of Generations [Phases]:
1-Phase [Egg/Seed-Adult]: microbes, plants, most animals
2-Phase [Egg-Larva/Vegative-Adult/Reproductive]: insects, coelenterates, bryophytes, cestodes, molluscs, protozoans
3-Phase [Egg-Larva 1-Larva 2-Adult]: trematodes
4 Reproductive Strategies: Many young widely-dispersed [r] or few young narrowly-dispersed [k]
5 Population Dynamics: Life-table, Size, Competition, Solitary or Aggregations, Social Organizations
6 Habitat and Isolate: Size, Degree of Isolation, Vertical Stratification, Horizontal Discontinuity, "Edge" Effects, Land-Water Ecotones, Lowland-Highland Ecotones
7 Trophic Dynamics: Herbivory, Detritivory, Predation [Predator-Prey], Parasitism [Host-Parasite]
8 Interspecific Interactions: Symbiosis, Protocooperation, Mutualism, Commensalism

[C] ECOSYSTEM OR COMMUNITY DIVERSITY

1 Energy Flow: Photosynthesis, Chemosynthesis, Grazing Pathways, Detritivore Pathways
2 Material Cycles: Nutrients, Water, Biomass, Production, Decomposition
3 Spatial Scales: Biotopes or Mosaics, Landscapes, Regions [Meso-scale], Global [Macro-scale], "Edge" Effects [Horizontal, Vertical]
4 Temporal Scales: Days, Weeks, Months, Years, Decades, "Generations", Centuries, Millennia
5 Information Diversity: Genetic, Species, Community, Landscape, Cultural

SOURCE: J.I.Furtado, based on NRC [1989]

3.2.7 Areas of Endemism and Radiation

International priorities and regional action plans for conserving biological diversity must consider areas of endemism and high species and habitat diversity under threat from resource transformation pressures. There are 12 countries mainly in the tropics which are very rich in species diversity ["megadiversity"] and account for 60-70 % of global diversity [Wilson 1988]:

* Brazil	* Colombia	* Ecuador
* Peru	* Mexico	
* Zaire	* Madagascar	
* Australia		
* China	* India	
* Indonesia	* Malaysia.	

These correspond somewhat to the regions of high endemism ["hotspots"] in tropical forests [Myers 1988]:

* **Atlantic Brazil**	* **W Amazonian uplands**
* **W Ecuador**	* **Colombian Choco**
* **Madagascar**	
* **Eastern Himalayas**	
* **Peninsular Malaysia**	* **Northern Borneo**
* **Philippines**	
* **New Caledonia**	* **NE Australia**.

These areas have been among the centres of origin of cultivated plants ["Vavilov Centres"]:

* **S Chile**: Potato
* **S Brazil and Paraguay**: Cassava, Peanut, Cacao, Rubber, Pineapple
* **Peru, Ecuador and Bolivia**: Sweet Potato, Potato, Lima bean, Tomato, Papaya, Tobacco, Sea Island Cotton
* **S Mexico and Guatemala**: Corn, Common bean, Pepper, Upland Cotton, Sisal Hemp, Squash, Pumpkin, Gourd
* **Ethiopia**: Wheat, Barley, Chickpea, Lentil, Pea, Teff, African Millet, Flax, Sesame, Castor bean, Coffee
* **Mediterranean**: Wheat, Hulled Oats, Broad bean, Cabbage, Olive, Lettuce
* **Near East [Asia Minor]**: Wheat, Barley, Rye, Red Oat, Chick pea, Pea, Lentil, Blue Alfalfa, Sesame, Flax, Melon, Almond, Fig, Pomegranate, Grape, Apricot, Pistachio
* **Afghanistan, Pakistan and NW India [Central Asia]**: Wheat, Rye, Pea, Lentil, Chickpea, Sesame, Flax, Safflower, Carrot, Radish, Pear, Apple, Walnut
* **Indo-Burma**: Rice, African Millet, Chickpea, Mothbean, Rice bean, Horse gram, Asparagus bean, Eggplant, Taro Yam, Cucumber, Tree Cotton, Pepper, Jute, Indigo
* **Thailand, Malaysia and Indonesia [Indo-Malaya]**: Yam, Pomelo, Banana, Coconut
* **C & E China and Korea**: Naked Oat, Soybean, Adzuki bean, Common bean, Leaf Mustard, Apricot, Peach, Orange, Sesame, Chinese Tea

In the marine environment, the Indo-Pacific archipelago, the western Indian Ocean and the Caribbean sea have high species diversity. Isolated oceanic islands [e.g. Hawaii], lakes [e.g. Baikal] and mountains [e.g. New Guinea] also have high endemism. Large areas [e.g. tundra, deserts, open sea] have low species diversity but are important for supporting migratory species. International conservation priorities and regional action plans should include **consideration of large areas with high and low diversity, and small areas with high endemism.**

3.2.8 Depositories and Repositories

Depositories of biological diversity and repositories of information on biological diversity occur in various forms. Many of these are private and not readily accessible to the public; and many are in metropolitan or industrialised countries that have had a colonial history in the tropics, in which case they are also not readily accessible to working specialists in tropical countries. Depositories consist of herbaria and museums for preserved material; zoos, botanical gardens and culture collections for live material conserved ex-situ; and protected areas for live material conserved in-situ. Repositories consist of indexes of collections and surveys, data banks and networks of information systems containing geographic, resource and environmental data. Depositories and repositories are important not only for authenticating material and information collected in surveys, but also for the holding of material and information about it and promoting its use in the search alternative livelihoods.

Inadequate information was available to examine this range of institutions. For example, the nine international agricultural research institutions of the Consultative Group on International Agricultural Research [CGIAR] concerned with staple crops and species hold and test a germplasm collection of about 420,000 at a cost of about US$200 million a year; and this is coordinated by a tenth institution, the International Board on Plant Genetic Resources [IBPGR]. In spite of this massive effort, most of the wild relatives of these major crops and species have not been collected [Hoyt 1988], and therefore need to be protected in-situ. Similar information is required for other forms of living and preserved collections of genetic and species variability. In the Food and Agriculture Organization of the UN [FAO], important work on genetic resources and species adaptability has been carried out by the Plant Production and Protection Division and the Forest Resources Division, and to a lesser extent by the Animal Production and Health Division and the Fishery Resources and Environment Division, at an estimated cost of US11.5 million per annum. For plants, there is an international legal undertaking with a Commission on Plant Genetic Resources made up of 114 countries. This Commission promotes [1] a network of base collections, [2] a global information and early warning system, [3] a network of in-situ protected areas, and [4] the Tropical Forest Action Plan. It provides an international forum for donors and users of germplasm, an international fund to promote conservation and use of germplasm, and coordination between governmental and private institutions and between plant breeders and farmers. Under its auspices, for example, a systematic set of priorities is developed every five years by an Expert Panel on Forest Genetic Resources, to review regions and species in relation to:

* their importance for specified end uses [industrial wood and pulp, fuelwood and energy, and other structural and chemical uses] on a three-point scale [highest, considerable and some actual importance]; and

* their operational priority [urgent, within a biennium, within a quinquennium, and completed] in terms of exploration [botanical, genecology], evaluation [collection, testing], conservation [in-situ, seeds, ex-situ] and utilization [bulk supplies, individual selection and breeding]

Through such a review mechanism involving the collaboration of all countries and their institutions, the FAO Forest Resources Division spends about US$400,000 a year on seed procurement [US$85,000], ex-situ conservation [$10,000], in-situ conservation [$60,000], information dissemination [$95,000] and on directory management [$150,000]. Furthermore, the Panel has identified global conservation priorities in terms of fuelwood, food, fodder and multipurpose species, species for arid and semi-arid regions, nitrogen-fixing species and species of special importance [bamboos, rattans, mangroves], and endangered species endemic on islands. A methodology has been developed for a broad approach to conserving forest genetic resources in this manner [FAO 1975], which could be adapted for other areas of genetic and species diversity of importance to human well-being.

The classification of habitats and ecosystems based on species associations and biotopes is still inadequate for the tropics and the marine environment. It is difficult to develop especially in areas of high diversity where taxonomic uncertainties prevail. Nevertheless, it is needed for characterising spatial areas used for in-situ and ex-situ conservation. The World Conservation Union [IUCN 1983] has devised 10 categories of protected areas based on objectives and criteria:

- I Scientific Reserve, Strict Nature Reserve
- II National Park
- III Natural Monument, National Landmark
- IV Nature Conservation Reserve, Managed Nature Reserve, Wildlife Sanctuary
- V Protected Landscape
- VI Resource Reserve
- VII Natural Biotic Area, Anthropological Area
- VIII Multiple Use Management Area, Managed Resource Area
- IX Biosphere Reserve
- X World Heritage Site [Natural]

These protected areas have not been assessed in terms of their habitat and ecosystem diversity, and the genetic and species diversity they contain. There is a need to test these protected areas for biological diversity based on biogeographic theory [Wilson 1988]. Roche and Dourojeanni [1984] have assessed their suitability for conserving genetic, species, and habitat and ecosystems diversity in the tropics on a five-point scale using experts with experience in the tropics [Table 6]. Four categories of protected areas appears best suited for conservation of genetic and species diversity: National Parks [II], Managed Resource Areas [VIII], Managed Nature Reserve [IV] and Strict Nature Reserve [I]; and among the managed nature reserves [IV], the best are the production and protection forest reserves, and the fauna reserves. Protected areas need to be carefully studied as <u>in-situ</u> depositories of biological diversity, since most of them are small and therefore prone to degradation.

Depositories of and repositories on biological diversity are relatively easy to establish but difficult to maintain. For example, while depositories of global significance like the Herbarium of the Singapore Botanical Gardens and the zoological collection of the Raffles Museum in Singapore are being maintained, they are barely being used in the survey of biological diversity of the region. **There is a need to assess the state of depositories curating genetic and species diversity <u>ex-situ</u>, and [of protected areas] harbouring unique and representative habitats and ecosystems <u>in-situ</u> especially in tropical and marine environments; as well as of repositories holding information on biological diversity at different levels.**

Depositories and repositories are expensive institutions to maintain. The International Board on Plant Genetic Resources spends about US$20-25 million per annum on maintaining its germplasm collection. The cost of establishing a gene bank for India was about US$10 million and involved support from the Ua.S. Agency for International Development; whereas the cost of a regional gene bank for Southern Africa amounts to US$12 million per year for 20 years with support from the Nordic countries. The collation, evaluation, storage and dissemination of conservation information by the World Conservation Monitoring Centre [WCMC] costs about US$1.7 million per annum, with the Centre using a network approach to store environmental and resource information on a geographic basis. On the basis of the availability of US$0.25 million per country to revive its sites and institutions, the initial cost of technical assistance for depositories and repositories could be about US$30 million per annum.

Table 6: Evaluation of Protected Area Categories for Genetic, Species and Habitat Diversity Conservation

CATEGORIES: CRITERIA:	I	II	III	IV	V	VI	VII	VIII	IX	X
Representative of biodiversity	4	5	1	3	1	3	2	3	2	1
Representative of rare or endangered species	5	4	2	3	1	3	2	3	3	2
Area of nation	1	4	1	3	1	3	3	5	1	1
Application in the tropics	3	5	2	5	1	4	4	5	2	2
Effective conservation status	5	5	3	5	1	1	1	3	3	5
Potential for effective management	1	2	1	4	5	3	4	5	3	1
TOTAL	19	25	10	23	10	17	16	24	14	12

SOURCE: Roche and Dourojeanni [1984]

3.2.9 Socio-Economic Research

Conservation of biological diversity is hardly incorporated into the "cost-benefit" analysis of development projects. In being treated as an externality, biological diversity is often overlooked because of difficulties in its quantification and monetisation. Even impact assessment procedures do not often take account of the state of biological diversity in tropical and marine environments because of problems of taxonomic uncertainty. There is a need to explore ways of expanding the "cost-benefit" approach to accommodate impacts on and trade-offs of biological diversity in terms of:

* **Costs and benefits**: maximising net gains to human welfare during the life-cycle of the resource by listing of all gains and losses, quantifying wherever possible and moneti sing as much as possible;

* **"Distributional" objectives**: by income and social categories especially of disadvantaged communities;

* **"Spatial" equity**: or benefits to particular regions; and

* **"Developmental" objectives:** as instruments of dynamic change at local, provincial or national levels.

Innovations in technology for intervening in ecological processes and transforming natural resources into goods and services for human welfare have out-stripped human capability in management. As a consequence, biological diversity is being directly and indirectly destroyed or degraded. Technological interventions which cause the degradation and destruction of biological diversity are not only large-scale but, also, small-scale. There is no standardised approach for classifying impacts of technology and for measuring the magnitude of their effects against some standards, in order to facilitate comparison of development and conservation aspects of projects, and promote the exchange of experiences. **There is a need therefore for a standard international approach for assessing the effects of various technologies threatening biological diversity, and for promoting an exchange of experiences, and for enabling integrated assessments of biological diversity based on their multiple outputs or benefits [e.g. energy, food, industrial materials] using an expanded "cost-benefit" approach.**

There were no cost estimates available for socio-economic research, except for the US$0.5 million per annum in Chile for assessing heritage areas. On the basis of the availability of US$0.25 million per country for surveys and technical assistance, the cost estimate for socio-economic research could be about US$30 million.

3.2.10 Education and Training

The most important constraint to the conservation of biological diversity on a regional global scale is the shortage of skilled expertise in various facets of the problem especially in the tropics and in the marine environment. This is particularly the case with developing countries in the tropics. **There is a need therefore to give training of technical expertise in taxonomy and classification, autecology and community ecology, curation and husbandry, information storage and retrieval, and in survey and monitoring techniques, a high priority for the conservation of biological diversity.** In Chile the needs for education and training have been estimated at US$0.65 million per annum, while in Denmark expenditure on conservation education and training is about US$1 million per annum. The need for an additional 7,500 taxonomists alone would cost about US$340 million. Realising that this is an important area, the estimate for initiating education and training could be about US$100 million per annum.

3.2.11 Management Strategies and Plans

Government and inter-governmental administrations are well organised already according to development sectors which are the source of environmental and social impacts affecting the conservation of biological diversity. They already spend vast sums of money managing protected areas. For example, Denmark spends about ~~US$3.5 million per annum on managing its protected areas, Chile~~ about US$6 million per annum and Finland about US$7 million per annum. The Food and Agriculture Organization of UN spends about US$21 million per annum on protected areas management. Management strategies and plans should concern not only areas rich in biological diversity, but also those areas under threat. The World Conservation Union [IUCN] has been promoting national conservation strategies in many countries to take stock of environment and development issues; and such plans need to be taken forward to implementation with the involvement of the development sectors in protecting and rehabilitating their resource and environment base. **It would be effective therefore to enlist the involvement of the development sectors in regulating their activities by expanding their scope and coordinating their work in conserving biological diversity.** On the basis of the availability of technical assistance US$0.5 million per country and region per annum, the cost estimate for stimulating management strategies and plans could be at least US$75 million per annum.

3.2.12 Monitoring

Effective regional action plans will require monitoring and evaluation of actions taken to conserve biological diversity. The Global Environment Monitoring System [GEMS] has been established under the United Nations Environment Programme to undertake this task. It works effectively through national and international networks which are concerned with one of the following elements:

* Environmental pollutants
* Long-range transport of pollutants and their effects such as acid rain
* Marine pollutants and living marine resources
* Climate and atmosphere
* Renewable natural resources.

A geographical data management system, the Global Resource Information Database [GRID] integrates data-sets to address specific environmental problems; and regional nodes for data management are being established, which should facilitate regional action plans for conservation. The World Conservation Monitoring Centre [WCMC] is a network node for data on biodiversity by species, areas and trade. It captures, manages and disseminates data and works with its network partners to verify data. The WCMC has a budget of about US$1.7 million a year half of which are its operational costs, and a quarter of which are connected to specific projects. This kind of system can help to make projections for areas lacking or possessing unreliable data. For example, the GEMS network facilitated the development of the estimate that a population of 1 million elephants in Africa at a growth rate of 5% per year could be expected to produce a harvest of 400 tonnes of tusks per year. This kind of information is very important for the conservation of biological diversity. **There is a need to ensure that an information management system is integrated into the regional action plan.**

Data bases are expensive to maintain and modernise. The International Whaling Commission spends about US$1 million per annum in monitoring the whale stocks; and Denmark spends about US$1 million per annum monitoring the protected areas and the environment. On the basis of technical assistance being available at US$0.25 million per country and US$1-2 million per region per annum, the additional cost of monitoring biological diversity could be about US$100 million per annum.

3.2.13 Conservation and Sustainable Technologies

Regional action plans will need to survey, identify and document innovations in conservation technology at the local level especially those that are sustainable, so that they may be demonstrated widely within countries and regions. There were no cost estimates available for this item. However, studies and technical assistance on conservation technologies could cost at least US$20 million per annum.

3.2.14 Priority Projects

The regional action plans should include projects demonstrating conservation of biological diversity in rich and poor terrestrial and aquatic environments. There were no estimates available for such items. Such projects should be organised on a regional basis to allow for inter-comparisons, and could initially need about US$40-50 million per annum.

3.3 Benefit to Local and Indigenous Populations

The regional action plans should be used to benefit local, particularly indigenous, populations. This could take the form of studies and technical assistance on the rights of indigenous peoples, on documenting traditions transmitted orally, and priority projects demonstrating the modernisation of technologies used in sustainable harvests. Such plans need to have two basic ingredients in order to ensure benefits to local and indigenous populations:

[1] Focus on Traditional Approaches: Involvement of the local and indigenous communities in regional action plans on conservation of biological diversity can provide new information of value to the public. This is particularly true where traditional knowledge has been orally transmitted. To make the action plans relevant locally and regionally, they could address one or more of the following issues concerning plants, for example:

* Location of traditionally-valued plants;
* Traditional uses of these plants for food, clothing, shelter, medicines, etc;
* Traditional ways of growing and harvesting these plants;
* Traditional ways of preparing these plants for different uses; and
* Biochemical assays of the active ingredients of these plants.

[2] Balanced Management: Local and indigenous communities are usually disadvantaged in comparison to urban and industrial interest groups in terms of organisation and access to political power. Their interests must therefore be managed sensitively and in a balanced manner, so that they too benefit from conservation and development programmes. The precise nature of their involvement and benefit would have to be examined in detail at a national and regional level.

There were no estimates available for the cost of this item. On the basis of US$0.9 million per annum spent on the rights of indigenous peoples in Chile, the additional funds required for studies, technical assistance and priority projects involving indigenous people could be around US$100 million per year.

3.4 Emergency Action Plan for Protected Areas

3.4.1 Protected Areas System

A global strategy for conserving biological diversity should incorporate an emergency action plan for protected areas that require special attention, since many of these are threatened by their small size. Emergency action could take the form of surveys of threatened species and small and threatened areas, restoration and rehabilitation of degraded areas, and management plans for threatened areas. There was little information available on this subject. The World Conservation Union's 10 categories of protected areas are being aggregated into six in a revised framework [Table 7] in which their conservation objectives have been defined clearly [Table 8] [Eidsvik 1990]. There is a need for an ecological evaluation of these revised categories in relation to both biophysical and socio-cultural processes. Collectively, 4,545 sites have been protected covering 4.85 million sq km [Table 9], which constitutes 3.7% of the land area. Most of these sites are small and therefore prone to "edge" effects and erosion of biological diversity. Their value for conserving biological diversity in the tropics has been questioned [see earlier]; and needs review in relation to biophysical and socio-cultural processes that make them sustainable [Table 10] [NRC 1989]. Tropical terrestrial and marine habitats and ecosystem types are inadequately represented among these protected areas, most of which have not been properly surveyed. It has been estimated that the management of these protected areas cost about US$200 million per year [H.E. Eidsvik, pers, comm.] which is low at US$40 per sq km in comparison to US$3,000 per sq km for restoring degraded lands in Europe and US$400 per sq km for managing rhinoceros habitat in Africa. There is a need therefore to **assess the protected areas in the tropical and marine environments in relation to the ecological and socio-cultural processes that enable them conserve biological diversity, and to hierarchical linkages that could make them useful for global monitoring like the Biosphere Reserves.**

3.4.2 Restoration of Degraded Areas

Most protected areas in the tropics and in the marine coastal zone are of small size [below 25 sq km] and hence prone to degradation. There is a need to **rehabilitate them in as flexible a manner as possible** [Table 11] [A. Lugo in Hadley and Schreckenberg 1989]. Rehabilitation and restoration of degraded areas is expensive. In Denmark about US$10 million is spent per annum on restoration of degraded areas, and a further US$3.5 million per annum on the management of threatened areas. The cost of rehabilitating Madagascar is about US$6 million per annum over 20 years. Landscape and seascape rehabilitation and restoration is thus an expensive proposition.

3.4.3 New Protected Areas

The tropics and the marine environment are particularly under-represented in the system of protected areas. There is a need to establish new protected areas in these environments especially in relation to an examination of these biomes on a species association basis, so that at least 10% of their area is protected for conserving biological diversity.

The costs of an emergency action plan for protected areas are difficult to estimate. Based on the need for rehabilitating Madagascar at US$6 million per year over 20 years and the expenditure of US$10 million per year in landscape rehabilitation in Denmark, there is a need for hundreds of millions to units of billions US$ for the emergency action plan.

Table 7: A Framework for Conservation Areas

CATEGORIES & GENERIC NAMES [and special designations] R= Reserve, P= Park A= Area, S=Sanctuary	HUMAN INTERVENTION (Low 0-10% / Mod 11-30% / High 31-50%)	RECOGNITION & LEGAL STATUS: Private Local Institutional	Provincial	National
I SCIENTIFIC RESERVES	++++++			
Strict Nature R	++	+	+	+
Ecological R	++++	+	+	+
Biogenetic R	++	+	+	+
Marine Sanctuaries	+++++	+	+	+
II WILDERNESS, NATIONAL PARKS & EQUIVALENT R	++++++++++			
Wilderness Areas	+++++		+	+
National Parks	++++++			+
State/Provincial P	++++++		+	+
Local/Tribal Parks	++++++++	+		+
Marine Protected A	++++++++++			+
III NATURAL & CULTURAL FEATURES	++++++++			
Geological Features & Fossil Beds	++	+	+	+
Natural Landmarks	+++++	+	+	+
Native Heritage A	++++++	+	+	+
Battle Fields & Archaeological Site	+++++++	+	+	+
IV HABITAT & WILDLIFE MANAGEMENT AREAS	++++++++++++			
Nature & Bird S	+++++++		+	+
Wildlife Ranching A	++++++	+	+	+
Wetlands & Refuges	++++++++++	+	+	+
Marine Management A	++++++++++	+	+	+
V ECODEVELOPMENT	++++++++++			
Protected Landscape	++++++		+	+
Seashores	++++++++		+	+
Scenic River, Trail & Waterways	+++++++++		+	+
Regional Nature P	+++++++		+	+
Recreation Areas	+++++		+	+
Landscape Conservation	++++++	+	+	+
Forest Reserves	+++++++	+	+	+
VI INTERNATIONAL DESIGNATION	++++++++++			
World Heritage Site	++++++	+	+	+
Ramsar Site	++++++++		+	+
Biosphere Reserves	+++++++++		+	+

Table 8: Primary Conservation Objectives of Protected Areas

	AREAS: OBJECTIVES:	I	II	III	IV	V	VI
A	Maintain Essential Ecological Processes and Life-Support Systems	1	1	2	2	2	1
B	Preserve Genetic and Species Diversity	1	1	2	1	2	1
C	Protect Aesthetic Values & Natural Ecosystems	2	1	1	2	1	1
D	Conserve Watersheds and their Production	3	2	3	3	2	2
E	Control Erosion, Sedimentation and Soil Depletion	3	3[W] 2[P]	3	3	2	2
F	Protect Habitat or Representatives of Rare and Endangered Species	2	1	2	1	1	1
G	Provide Opportunities for Ecotourism	3	3[W] 2[P]	3	2	1	2
H	Provide Opportunities for Research, Education and Monitoring	1	1	2	1	1	1
I	Stimulate Sustainable Use and Ecodevelopment	3	3[W] 2[P]	3	2	1	2
J	Protect Natural and Cultural Heritage	2	1	1	2	1	1

AREAS: I = Scientific Reserves, II = Wilderness, National Parks and Equivalent Areas, III = Natural and Cultural Features, IV = Habitat and Wildlife Management Areas, V = Ecodevelopment, and VI = International designation

OBJECTIVES: 1 = Primary Objective for Establishment and Management, 2 = A Secondary Objective but not always Included, 3 = Included as an Objective where Feasible and not in Conflict with 1 or 2

W = Wilderness Area, P = Parks

SOURCE: Eidsvik [1990].

Table 9: Protected Areas of the World

REALM	NO. OF SITES	AREA [sq km]
AFROTROPICAL	444	860,900
INDOMALAYAN	676	322,800
PALAEARCTIC	1,684	731,900
OCEANIAN	52	48,900
NEARCTIC	478	1,725,600
NEOTROPICAL	458	768,100
AUSTRALIAN	623	356,900
ANTARCTIC	130	31,200
TOTAL	4,545	4,846,300

SOURCE: McNeely, Miller, Reid, Mittermeier and Werner [1990]

Table 10: Criteria for Protected Areas

CRITERIA	CHARACTERISTICS
	[A] BIOLOGICAL
1 DIVERSITY	species, communities, habitats & ecosystems except pioneer communities, and climax communities of disrupted areas [e.g. shore]
2 NATURALNESS	lacking disturbance or degradation; of value to tourism and productive use, and to restoration of degraded areas
3 DEPENDENCE	on habitats and ecosystems, on ecological processes, edge effects and ecotones
4 REPRESENTATIVE-NESS	of habitats, communities, ecological processes and natural features
5 UNIQUENESS	of species, habitats and ecosystems; of regional and international significance
6 INTEGRITY	of ecological functions; self-sustaining
7 PRODUCTIVITY	of species and communities except eutrophic
8 VULNERABILITY	to degradation due to low stress tolerance

Table 10 [contd]

		[B] SOCIAL
9	**SOCIAL ACCEPTANCE**	supported by local human communities, by their traditions and rituals
10	**CULTURAL ATTRIBUTES**	of religious, historic and artistic significance
11	**CONFLICTS OF INTERESTS**	in human use [e.g. commercial harvests] requiring zoning
12	**BENCHMARK POTENTIAL**	as a control for measuring anthropogenic changes elsewhere [e.g. biosphere reserves]
13	**EDUCATION POTENTIAL**	for research and demonstration of species, habitats and ecological relationships]
		[C] ECONOMIC
14	**IMPORTANT SPECIES**	for breeding, resting or feeding of species of economic importance; hence zoning
15	**LOCAL RESOURCE ECONOMY**	dependence of local economic livelihood and size of harvest; hence sustainable yield
16	**THREAT MAGNITUDE**	from changes in use pattern [habitat or technologies] causing overexploitation of species with low breeding potential
17	**ECONOMIC BENEFITS**	of protection or restricted use to local and external economies
		[D] MANAGEMENT
18	**EFFECTIVENESS**	of patrol, monitoring and protection
19	**OPPORTUNISTIC**	reinforcing existing conditions and actions [e.g. extension of protected area]
20	**AVAILABILITY**	for protection and management with the agreement of owners, or by acquiring tenure

SOURCE: NRC [1989].

Table 11: Strategies for Rehabilitating Degraded Tropical Forests

* Maintain flexibility in the rehabilitation approach

* Be alert to environmental conditions

* Avoid specificity on the ultimate goals of rehabilitation

* Maximise vegetation cover

* Manipulate existing vegetation before attempting a substitution

* Use fallow to do most of the forest rehabilitation

* Restore tree cover as quickly as possible

* Be aware that nutrient cycling strategies may change through rehabilitation from phosphorus limitation to nitrogen limitation

* Develop species mixtures [associations] depending on their "ecological" combining ability

* Keep topsoil moist, cool and shaded

* Couple ecosystems to maximise their value, and accelerate rehabilitation [e.g. use treated urban sewage as irrigation water to accelerate tree growth]

* Maximise ecosystem complexity to optimise use of site resources, maximise protection from pests and diseases, and to minimise risks

* Use exotic tree species to foster native species through site rehabilitation

* Use multiple seeding techniques when in doubt as to what to plant, and let natural selection processes decide the best species combination for a site

* Create loci of species activity from which habitat rehabilitation occurs under the influence of biotic agents

* Use stressors to arrest succession at a desirable stage

SOURCE: A. Lugo in Hadley and Schreckenberg [1989].

3.5 Biological Diversity Research

Any global strategy for conserving biological diversity should consider support for research of value to management and to harnessing new information for economic growth and alternative livelihoods. There is need in particular to identify research on biological diversity in the tropics outside the main band of species currently exploited. This research process will involve identification, verification and authentication of biological diversity, promotion of its economic uses, and development of its sustainable uses. The literature available on this topic was limited.

Biological diversity research should be aimed essentially to address management issues concerning the ecological processes sustaining genetic, species and habitat and ecosystem variability [see earlier]. Research focus on questions of importance to management is particularly needed in view of the escalating threats to conservation:

* Genetic and species losses due to habitat fragmentation, modification or consolidation;

* Redundancies and compensations of species diversity at large scales in carbon, nutrient and hydrological cycles;

* Role of habitat and ecosystem diversity and fragmentation [mosaics] in landscape functioning;

* Role of species assemblages as indicators of environmental changes;

* Role of species associations in changing system dynamics;

* Species and functional diversity at land-water and lowland-highland interfaces; and

* Scaling of species interactions and ecosystem and landscape functions.

Four themes should be considered in this research programme [di Castri and Younes 1989]:

[1] The relation between species and landscape or seascape diversity with respect to change:

This research theme should enable understanding of the role of disturbances on the structure and function of habitats, ecosystems and landscapes or seascapes at different spatial scales in relation to genetic and species diversity, especially in the tropics and in transitional zones [e.g. land-water ecotones, estuaries and the Mediterranean]. The null hypothesis being tested should be that genetic and species diversity are more important at micro- or small scales than at meso- or large scales because of buffering and compensatory effects in the latter. The approach taken to understand these relationships should be that of using comparative river basins, or landscape or seascape units with reference to:

* species diversity, demography and biogeography;

* inter-specific interactions, both positive and negative, especially in terms of edge effects and ecotones;

* sources and sinks for water, minerals and gases, especially on the role of microorganisms in nutrient entrapment, nitrogen fixation, decomposition, soil and water quality, symbiosis and environmental detoxification; and

* productivity.

[2] Global biogeographic classification system:

This research theme should enable the development of a standard global biogeographic classification system for comparing and contrasting ecosystems and landscapes or seascapes, and for identifying unique and representative areas, in relation to change. The null hypothesis being tested should be that species diversity is strongly correlated to ecological processes at landscape levels, at different spatial and temporal scales [suggesting hierarchical levels] and in indicating environmental changes at the regional or meso-scale. The approach needed to understand these relationships should be that of using a hierarchical network of observatories, ecological patterns for assessing habitat loss and species associations as indicators of ecological processes, with reference to:

* small discontinuous areas with low species diversity [e.g. lakes, islands, oases];

* large but patchy areas with rich species diversity [e.g. lowland forests, continental shelves, land-water ecotones]; and

* large areas with relatively even species diversity [e.g. open seas and oceans, tundra].

[3] Species diversity as long-term indicators of change:

This research theme should enable the understanding of changes in species diversity in relation to changing habitats and landscapes over time, to land use, fragmentation and gradients, to ecosystem functions, and to habitat losses, pollution, invasions and epidemics. The null hypothesis being tested should be that there are very few historical and reliable data sets to facilitate understanding of global change. The approach needed to understand these changes is a focus on major land- and sea-scapes by institutions having secured support, historical data sets and an ability for undertaking integrated research, with respect to:

* Population and community structure; and

* Ecosystem functions particularly productivity, material fluxes, climatic variations, hydrological cycles and substrate changes.

[4] Effective conservation of genetic resources of wild species:

This research theme should focus on the conservation of germplasm of wild relatives of species of potential economic value. The null hypothesis being tested should be that protected areas have been assumed to safeguard the germplasm of useful species, but their effectiveness has never been assessed. The approach taken in this study should be to understand the relationship of protected areas to their effectiveness in protecting biological diversity, to the appropriateness of their management systems, and to the effectiveness of small populations and networks of complementary ex-situ germplasm centres, with respect to:

* Rare and endangered species;

* Species of economic importance;

* Species of value in ecosystem restoration and rehabilitation; and

* Isolated species.

Research on biological diversity conservation should thus focus on under-utilised and marginal species, on species associations and community types, and on landscape mosaics. It should be undertaken through international collaboration, and linked to the International Geosphere-Biosphere Programme [IGBP] which currently does not focus on the conservation of biological diversity, nor involves the developing countries in any significant manner [only 3/24 participating countries are developing].

Some ingredients of collaborative interdisciplinary research have been outlined by Swift [1984]. Such research should address socio-economic issues since biodiversity conservation can be beneficial as in the case of Canadian bird conservation [Table 12]. It is difficult to cost biodiversity research without detailed consideration of the issues being studied and consultations with potential partners, but indicative unit costs may be helpful [Table 13]. American non-governmental institutions currently support biodiversity research and training amounting to US$37 million per year. The U.S. Agency for International Development has been mandated to increase its allocation for biodiversity research. The U.S. National Science Foundation has agreed to allocate additional resources for biodiversity research and training as follows [NSF 1989]:

* Inventory: US$5 million per year rising to $20 million; Microorganisms US$8 million per year rising to another $20 million; Ecological research at US$5 million per year;

* Conservation Biology, Restoration Ecology and Environmental Management: US$3.5 million per year rising to $10 million;

* Education and Public Awareness;

* Socio-Economic Aspects of Biodiversity Conservation: US$1 million per year; and

* Research and Management in Developing Countries: US$2 million per year.

The Food and Agriculture Organization of UN spends at least US$300 million per annum on testing and breeding programmes; and the Consultative Group for International Agricultural Research spends another US$200 million per annum. On the basis of these estimates, it would be reasonable to expect an additional US$100-300 million per annum for broadening the use of species diversity authenticated, and for conserving biological diversity.

Table 12: Economic Value of Canadian Birds especially Waterfowl, 1981 [C$ 1981]

ITEMS	ALL WILDLIFE	WATERFOWL & BIRDS
Participants	41 million	16 million
Direct economic benefits [Net annual value]	$779 million	$347 million
Capitalised Value [@ 5% discount rate]	$15.6 billion	$6.9 billion
Expenditures by Participants/Year	$4.2 million	$2.0 million
Gross Business Product per year	$8.8 billion	$4.1 billion
Gross Domestic Product per year	$5.2 billion	$2.4 billion
Personal Income per Year	$3.0 billion	$1.4 billion
Government Revenue per Year [Taxes]	$1.9 billion	$870 million
Employment per Year	185,000	86,000

SOURCE: Filion [1987], Jacquemot and Filion [1987]

Table 13: Unit Costs for Biodiversity Research

ITEMS	COSTS [US$/Year]
Technical Assistance	$ 12,000
Research Grants	$ 50,000
Information Management & Evaluation	$200,000
Wildlands Demonstration Project	$ 50,000
Pilot Conservation Data Centres	$150,000
Demonstration Protected Areas	$150,000
Demonstration Buffer Zones to Protected Area	$200,000
Pilot Conservation Education Project	$100,000
Technical Assistance for Research & Training	$300,000
Support for Local Economic Analysis	$100,000

3.6 Traditional Uses of Biological Diversity

A global strategy should include an assessment into the ways in which indigenous people harvest useful substances from tropical wild lands and waters on a sustainable basis. Traditional knowledge has been used to harvest of useful substances from natural biological diversity at different intensities causing low level perturbations. Materials harvested thus have been used for fuel, staple food [carbohydrates, proteins, water], food supplements [minerals, vitamins], beverages, psychedelics, medicines, clothing and construction materials. A variety of technologies have been used traditionally to harvest the desired products often in association with profound spiritual rituals for conserving the resource. Understanding the cultural context of this process has potentially profound value to the evolution of the conservation ethos. In plants for example, these technologies take the form of pruning and coppicing, using seeds and fruits and bark, collecting resins and secretions, tapping, using whole organisms, burning and planting and culturing. **Six steps are necessary in order to conserve cultural diversity and benefit from it:**

[1] Giving appropriate value to the traditional rights, knowledge and skills of indigenous peoples;

[2] Taking special measures to protect the rights of indigenous peoples;

[3] Providing information on traditional resource management systems;

[4] Promoting the application of traditional wisdom to modern resource management;

[5] Designing projects which benefit indigenous peoples; and

[6] Designing projects which benefit from traditional knowledge.

There were no estimates available for this item in the strategy. On the basis of an availability of US$2-5 million per annum for each region, the cost of additional funds to research into the ways in which indigenous people harvest useful substances could be in the low hundreds of million US$.

3.7 Patent Protection and Technology Transfer

A global strategy for conserving biological diversity should include the cost of obtaining patent protection for new medicines and other chemicals derived from tropical species, and the cost of technology transfer. Discoveries of new products and processes where patent protection is useful occur at a very low rate of 1/100 or 1/1000 where mass screening techniques are used. In selective screening techniques involving considerable knowledge and experience, the success rate of discovering interesting compounds may be as high as 1/10. While it is advantageous to patent new products or processes, experience has shown:

[1] that very few of the patents are actually used, thereby casting a shadow of doubt on the utility of patenting; and

[2] that where useful patents have been struck, they are bought by more advanced institutions, deciphered and replaced by new and enhanced patents.

Patent protection is thus complicated and requires sophisticated scientific and legal know-how if developing tropical countries are to benefit from them.

While plant breeders' varieties are protected by patenting and organisations like the International Union for the Protection of New Varieties of Plants [UPOV], the traditional source of variability has been somewhat overlooked hitherto. 90% of new varieties are from developing countries in the tropics where farmers and indigenous peoples have contributed to their selection over millennia [Mooney 1983]. 25% of the pharmaceuticals sold today are of plant origin and generate expenditures in R&D of the order of US$4 billion a year, and sales of the order of US$8 billion a year. The total contribution of wild germplasm to the America economy, for example, has been estimated to be US$66 billion, with a wild tomato from Peru alone contributing US$8 million a year; and drugs from the Madagascar periwinkle alone generating sales of US$160 million a year. The farmers' rights have therefore been adopted by the 158 countries of the Food and Agriculture Organization of the UN. It establishes an International Fund of about US$500 million through a levy on commercial patents derived from germplasm collected from farmers in the developing countries of the tropics. It costs a fraction of US$1 million to secure a good comprehensive patent protection. Where biotechnological advances have been made on the access to germplasm of tropical species, there will be need to develop some mechanism for compensating the natural source of the original genetic material, and even promoting the transfer of technology. On the basis of US$1-5 million per annum being available per region, additional funds of at least US$100 million would be required for promoting patent protection and technology transfer in tropical developing countries.

4 CONCLUSIONS

A global strategy for conserving biological diversity especially in the tropics and in the marine environment should be developed in view of serious and emerging threats to it. One of these threats is the high population and economic growth rate of tropical developing countries which is potentially destabilising and which exhibits little sign of slowing down. Additional funds should be secured and targeted for conserving biological diversity and promoting the search for alternative economic livelihoods for people in these countries. An estimate in the high hundreds to units of millions US$ needs to be secured for implementing such a global strategy.

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ANNEX

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