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Bioinformatics Implications of the International Biodiversity Conventions

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Abstract: Many nations have now confirmed their commitment to the principles of Agenda 21 by becoming Parties to the Convention on Biological Diversity, and many have joined four other treaties related to biodiversity conservation. In addition many are signatories to treaties directed at stabilisation of the global environment, such as the Framework Convention on Climate Change (FCCC), and the Montreal Protocol on restricting ozone-depleting substances. These treaties will have direct consequences on the way in which biological information is gathered, organised, maintained and disseminated within countries, that is on national "bioinformatics". Many of the treaties have, or will have, defined reporting requirements to the global community which directly require, or indirectly imply, the need for biological information systems. This is in tune with the increasing recognition that the key to national strategy development and wise decision making on the sustainable use of biological resources and the equitable sharing of benefits, depends on having systematically organised **information** (such as, inventories of biological resources, indicators of sustainable use, indigenous knowledge, biotechnology, gene-banks, trade in species).

The information which nations must organise and manage to respond to specific and implied requirements of these treaties is complex, has scientific, economic and policy components, and transcends the divisions between conventional resource sectors. This presents significant challenges to the development of the required enabling bioinformatics capabilities which are taxing to all nations, but particularly strain the capacity of developing countries. For many countries it will mean the re-engineering of approaches to biological data management to effectively and efficiently serve both national strategic and operational needs, as well as meet the reporting obligations to all the relevant treaties.

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INTRODUCTION

Over the past 20 years nations have agreed to a number of international treaties intended to ensure the on-going sustainability of the biota of this planet. Five of these are completely or closely related to biodiversity:

The Convention on Biological Diversity (CBD),
The Convention on International Trade in Endangered Species (CITES),
The Convention on Migratory Species (CMS or the "Bonn" Convention),
The Ramsar Convention on Wetlands of International Importance, and
The World Heritage Convention (WHC).

These treaties, in conjunction with others aimed at stabilisation of the atmosphere (the FCCC and Montreal Protocol), or at specific aspects of environmental degradation (Convention to Combat Desertification) **may** mark the beginning of a new era of international co-operation wherein nations act in consort to ensure the sustainability of the biosphere (ref. 1). It is “early days” yet. The next few decades will tell us if the enthusiasm and sense of urgency which surrounded the Earth Summit in Rio in 1992 will itself be sustainable. We must note that over 100 other international environmental treaties have been agreed during the last century (see for example Table 10.1 of ref. 2) many of which have been forgotten or are ignored. If the hope and impetus engendered by the Earth Summit is to bear fruit, this new wave of major treaties must be fully and efficiently implemented, and must increase participation so as to be truly global.

The five biodiversity treaties currently have overlapping but differing constituencies. The same suite nations are not signatories to all Conventions; key countries are conspicuously missing from some Conventions, and some countries are party to none.

Table 1: Participation in the Five Biodiversity Conventions

	CBD	**WHC**	**CITES**	**Ramsar**	**CMS**
No of Parties	162	148	124	93	51
Into Force	29/12/1993	17/12/1975	01/07/1975	21/12/1975	01/11/1983
Key Parties					
Brazil	✓	✓	✓	✓	X
China	✓	✓	✓	✓	X
Germany	✓	✓	✓	✓	✓
India	✓	✓	✓	✓	✓
Indonesia	✓	✓	✓	✓	X
Japan	✓	✓	✓	✓	X
Kenya	✓	✓	✓	✓	X
Malaysia	✓	✓	✓	✓	X
Tanzania	X	X	X	X	X
Thailand	X	✓	✓	X	X
UK	✓	✓	✓	✓	✓
USA	X	✓	✓	✓	X

It is a hopeful sign that these five treaties differ in several important ways from the long list of largely unsuccessful treaties of the past:

Firstly, although not all countries have joined, participation is extensive (none have less than 50 participating countries) and most include a broad spectrum of industrialised, emerging and developing nations. Secondly all of them require, in spirit or in fact, significant **information reporting and exchange.**

Moreover these treaties are children born in the new "Information Age". An Age which has at is command the information technology and infrastructure capacity to organise, communicate and exchange information rapidly and easily. The result is that "biodiversity information", formerly the domain of the notebook of the "naturalist", or the specimen in the museum, botanical garden or zoo, is now openly available to the full international scientific community, as well as the general public. One of the factors which will determine whether the treaties can in the long run achieve their purpose, is the ability of party nations, separately and collectively to take advantage of the appropriate tools of modern information technology ("informatics"). Moving towards this partnership will cause direct consequences to the way in which biological information is gathered, organised, maintained and disseminated within countries, that is, on national "bioinformatics" (ref. 3).

Note: *Bioinformatics is used here as a shorthand for information technology systems support for the management of biological and ecological data. It includes the application of modern computers, telecommunications, networks, and databases, as well as more specialised tools such as GIS, image analysis, and statistical and modelling software.*

BIOINFORMATICS IMPLICATIONS IN PRINCIPLE

Integration into National Strategies

The treaties insist or imply that consideration of biodiversity information must become integral to all national strategy development and decision making with regard to the utilisation of biological resources

This means consideration of scientifically sound biological and ecological data as part of the national policy planning process in forestry, agriculture, fisheries, land management and economic development, and in the regulatory regimes which affect a wide range of human activity - from industrial waste management to the use of motor vehicles or choice of household fuel (ref. 4).

Implications

National information systems and information flow must cross-cut traditional discipline boundaries, and bridge between the scientific and socio-economic sectors.

External Impacts

The treaties require an awareness of the impacts of one country's actions on the sustainability of the biological resources of others. This requires a knowledge of the resources at risk beyond national borders, and the potential consequences of actions and decisions on ecosystems.

Implications
Information must be exchanged and shared on a **regional** basis to compliment national information. In addition decision support systems are needed which are capable of forecasting consequences.

Reporting Requirements
The treaties require nations to report though a co-ordinating secretariat to a Conference of Parties on actions taken, and on summary statistics or indicators reflecting the level of implementation of the treaty.

Some examples of information required in national reports or submissions to the conventions:

- *information on trade in specimens of species included in Appendix I, II, and III* (CITES)
- *measures taken for the implementation of Article 6* (in situ conservation) *of the Convention* (CBD)
- *physical features, hydrological values, ecological features, notable flora and fauna …* (for a Ramsar Site)
- *the conservation status of migratory species listed in the Appendices* (CMS)
- *site management plan, development pressures, key indicators for monitoring the state of conservation …* (for a World Heritage Site)

Implications
Bioinformatics systems must be available to consistently summarise national actions, progress and the status of biodiversity.

It is abundantly clear that to meet these demands effectively and efficiently, countries must develop a national biodiversity information system - which must be closely linked with national economic and social information systems (including national statistical bureaux) (ref. 5).

BIOINFORMATICS IMPLICATIONS IN PRACTICE

Good decision making requires **good timing**, as well as good information. This means making the decision at a time when it is still possible to avert adverse consequences, or when proposed measures can have the best effect. The process of biodiversity data collection, integration and conversion into "information products" suitable for decision makers can be very time-consuming (even if assisted by modern computer systems). Just as it is necessary to have water management infrastructure in place to avert floods before they occur, there must be an "information management infrastructure" in place before particular instances of decision making are critical. This means having available in advance **essential "core" datasets** likely to be needed for a range of decision making purposes, having the **information systems** in place with the processing capabilities to be able to quickly produce the specific information products required, and **information exchange agreements and facilities** already established. This basic information management infrastructure must be developed to support of ranges or classes of biodiversity issues in anticipation of likely decision making scenarios and requirements (ref. 6). The information systems capabilities required will normally be with the specific expert institutions which are the key custodians of the essential core datasets.

Three main classes of data or information are required and are briefly described in the following.

Scientific Information

Scientific information includes observations on the condition and status of biodiversity, *e*ncompassing information on biosystematics, species, habitats, protected areas, wildlife, ecosystems, and biodiversity indicators. It also extends to genetic resources, bio-technology, environmental statistics and scientific methods and procedures for monitoring and modelling.

Informatics Implications

Biodiversity scientific information is highly varied and includes quantitative and coded tables, time-series as well as narrative and descriptive text. A common characteristic is that it is often spatially referenced – ie in map form or with reference to point locations. The needed bioinformatics technology includes database management systems, GIS, image analysis, statistical analysis (including time-series) and modelling (both dynamic and static). Further there is a need to be able to locate an extract descriptive text – often involving large quantities in disparate locations. This leads to requirements for keywording, indexing, hypertext linking, distributed networking, and for meta-database technology to assist in locating appropriate data sources.

Policy Information

This includes the policies, action plans, strategies, administrative procedures, institutional arrangements, and legal instruments – that is responses to issues, as well as information on the human factors, encompassing population, human health, social conditions, indigenous knowledge, and their relationships to biodiversity.

Informatics Implications

Such information is dominantly in text form with some statistical tables. Spatial referencing is usually to an administrative framework (provinces, municipalities, electoral districts). Thus text processing requirements dominate – including the use of micromedia and optical storage, along with statistical data bases and associated processing, although tolls like GIS may be required for integration with scientific information.

Economic Information

Economic information is essential to the concept of “equitable sharing of benefits” (CBD) to “wise use” (Ramsar), “sustainable use” (CMS) and so on. Included are measures of economic productivity as well as the valuation of biodiversity.

Informatics Implications

Such information is dominantly in statistical tables, and economic time-series – referenced to administrative areas, social groupings, or industrial sectors. Informatics analysis tools needed include time-series analysis, cross-sectoral modelling, GIS etc.

APPROACHES AND SOLUTIONS

Such cross-cutting integration presents undeniable challenges to informatics in all party countries. There can be no "formula solution" which one can advocate for all cases. Existing information systems are often strictly sectoral or vertical, serving the needs, for instance, of resource ministries such as forestry, agriculture, or fisheries. The cross-cutting requirements of a bioinformatics system demand a nationally distributed network approach. This may require re-thinking or "re-engineering", in order to provide a flexible, but nationally integrated approach which enhances rather than dilutes the specialised expertise of component institutions. The basic components of a national bioinformatics information system are shown in Fig. 1.

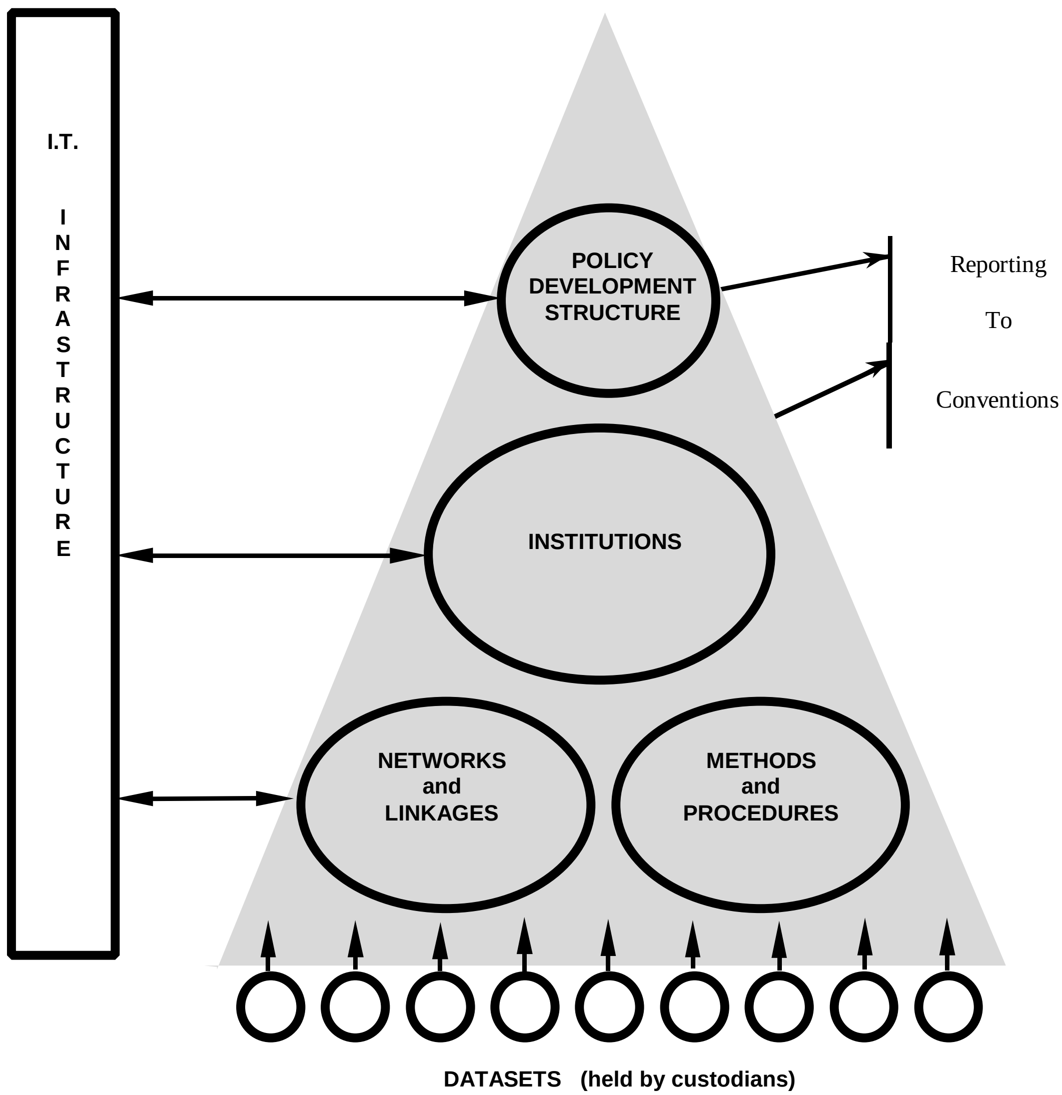

Figure 1: Components of a National Bioinformatics System

The major components serve to transform the raw data held by national custodians (museums, government agencies, NGOs, universities) into information suitable for decision making and summarised appropriately for reporting to the Conventions. There is a general upward flow of information through this structure, but it is not meant to imply centralisation or rigidity. Component institutions link together when appropriate to contribute to national policy and planning needs and reporting obligations to Conventions, while continuing to perform their normal mandated functions. Through-out the process these functions are supported by a national informatics infrastructure - the networks, computers, systems, and people, that mange and process the information.

The Policy Development Structure should provide for participation from multiple stakeholders and utilise information products which have been integrated from a range of data sources and institutions.

Strong Institutions, and accompanying human resources are a key component. These may be specialised to varying degrees and must co-operate with each other through formal and informal networks.

Standard Methods and Procedures for meeting decision maker needs includes putting in place procedures (and trained human resources) to determine and document information needs, to develop suitable products to fulfil those needs, and appropriate data standards to ensure that the information is meaningful.

Institutional Linkages and Networks are essential for all the relevant agencies and stakeholders to communicate to share data, information and expertise.

Information Technology Infrastructure is the support framework for all information management activities. This "infrastructure" includes the "nuts and bolts" of computer hardware and software, data standards and models, and the information exchange media, including computer networks. These are the vital arteries of information management.

Data - High quality data held by a series of qualified expert custodians is the foundation of good information management and good decision making.

For solutions and direction for the design of such a bioinformatics infrastructure we can look towards some other fields of endeavour where successful solutions are well established (trade, commerce, atmospheric and oceanographic sciences). Some of the elements of solutions are briefly outlined in the following:

Standards and Harmonisation

Biological information standards serve to enable useful data exchange, by making data compatible, and thus capable of summarisation, and further increases the meaning and hence the value of derived information. Some areas where standards or harmonisation principles are needed include

- taxonomy and biosystematics
- biological controls
- statistical and scientific methods e.g. for monitoring
- indicators, thresholds, and targets
- terminology e.g. for threats, actions, ecological classification
- harmonisation of Conventions e.g. in scheduling, reporting, information management

Information Systems Design

Biodiversity information systems should be developed and design using the principles, techniques and technological aids which are well established in other fields. This is essential if biological information is to correctly and significantly influence the policy and decision making process.

Clearing Houses and International Data Management Bureaux

Employ international clearing houses and centres of expertise to share scientific methods and knowledge – particularly to take maximum advantage of existing centres of excellence such as the CGIAR, Species 2000. The burden of integrating and maintaining biological data, and all the associated standards, need not be replicated in each country – rather international data management bureaux (and networks of such centres) can be utilised to provide professional custodianship and universal efficient access. This is again an area where the oceanographic and atmospheric sciences have been very successful and can provide valuable lessons.

National and International Data Archiving

The preservation of historical biological data is as important as more traditional socio-economic statistics, and systems of custodianship should be established to ensure that key information is maintained for future use.

Wise Use of Available Tools

A range of well-established information management tools are available which appear to be under-utilised in bioinformatics, including geographic information systems, modern DBMS, established statistical and time-series analysis software, and satellite remote sensing to monitor broad regional change.

IMPLICATIONS FOR DEVELOPING COUNTRIES

Developing countries need capacity building to strengthen **all** of the components of a national bioinformatics system. This includes institutional strengthening in scientific capability, for instance in ecology, taxonomy, bio-technology, and wildlife management. But this alone is insufficient. Capacity and skills need to be increased in policy formulation and implementation, in institutional networking, in standards and quality assurance, and in the informatics infrastructure needed to support these components. This latter includes strengthening of physical as well as human support infrastructure in telecommunications, computer hardware and software, and associated information analysis tools.

What is needed are multi-faceted integrated capacity building programmes that incorporate training (technical, as well as management and policy skills), institutional strengthening, networking (including how to gain from public participation) and technology augmentation. Most importantly, this type of capacity building will not only increase the ability of the country to effectively implement the biodiversity treaties, but in parallel, will strengthen national economic and social development planning capacity, thus serving multiple and mutually beneficial goals towards national development.

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