Biodiversity information on the Internet: cornucopia or confusion?

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Abstract. The range of information on biodiversity currently available via the Internet is reviewed and its accessibility, usefulness and relevance to biodiversity research and to policy decision making assessed. Commercial and non-commercial databases are reviewed. The future of information via the net is also reviewed, in particular the role of the 'Clearing House Mechanism' of the Convention on Biological Diversity and the Biodiversity Conservation Information System.

Key words. Biodiversity, bioinformatics, internet, conservation, ecology, databases, metadatabases, metaindexes, Convention on Biological Diversity (CBD), Clearing House Mechanism (CHM), environmental policy decision making, Biodiversity Conservation Information System (BCIS), Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA), intelligent agents.

INTRODUCTION

The last 2 years have seen an exponential growth in the use of the Internet for the dissemination of information, with large amounts of information potentially relevant to biodiversity and the environment. Information sources range from government organisations to universities to private individuals to commercial organizations, and the information provided ranges in format from plain text documents, to complex hyperlinked documents, to maps, photographic and GIS/GPIS images, to simple databases to complex searchable databases with sophisticated search engines, to meta-indexes (information about where to find information) and virtual libraries. Table 1 includes a number of examples of such information services.

The growth in the number of providers of information has coincided with rapid growth in number of users, and the number of those able to connect to the Internet. This has brought with it the expectation of freedom of access to information for all, and the promise (if not the full realization) of the right information at the right time for conservation biologists, ecologists, policy decision makers and others who need information about biodiversity. There is also increasing commercial interest in providing such information.

Meanwhile, the recognition of the importance of information in the conservation and sustainable use of biodiversity has never been greater. Both the Convention on Biological Diversity (CBD) and Agenda 21 give clear recognition to the importance of information and its effective management, and many national governments are increasing the resources applied to improving biodiversity information management (some with the support of the Global Environment Facility, GEF). At the same time international organizations are aware of the need to increase the availablity of the information to which they should have access.

Nonetheless, the environmental decision making process is moving faster than institutions can supply the relevant information, as Calestous Juma, Executive Secretary of the Convention on Biological Diversity (CBD), remarked at an International Workshop on Biodiversity Information at Imperial College, London, UK (15–16 July 1996). This point may seem to conflict with the fact that there is so much information about biodiversity on the Internet (see Table 2), but, by the very nature of the process, the information available is very variable, largely disorganized, and varying widely in quantity, quality and parentage.

Moreover, knowing where to look (and what to ignore) is a problem, and becoming increasingly so as the net expands and develops. At the same meeting,

Table 1. Examples of some internet sites for biodiversity information.

Organization	URL
Alaska Department of Fish and Game (ADF&G)	http://www.state.ak.us/local/akpages/FISH.GAME/adfghome.htm
Audubon Society	http://www.igc.apc.org/audubon/
Base de Dados Tropical (BDT)	http://www.bdt.org.br
Biodiversity Action Network (BIONET)	http://www.access.digex.net/~bionet/
Biodiversity and Ecosystems Network (BENE)	http://straylight.tamu.edu/bene/bene.html
Biodiversity Information	htt://www.uwsp.edu/acaddept/geog/biodivs.htm
Biodiversity Information Network BIN21	http://www.bdt.org.br/bin21/bin21.html
Biodiversity Resource Center	http://www.biodiv.com/biodiv.html
Bioline Publications	http://www.bdt.org.br/bioline
Bird Conservation	http://www.ornith.cornell.edu/Conservation/ConservationHome.html
Butterfly Website: Conservation and Ecology	http://mgfx.com/butterfly/ecology/index.htm
Canadian Biodiversity Information Network (CBIN)	http://www.doe.ca/ecs/biodiv/biodiv.html
Canadian Botanical Conservation Network (CBCN)	http://www.science.mcmaster.ca/Biology/CBCN/homepage.html
CERES Topic: Rare and Endangered Species	http://resources.agency.ca.gov/topic/rare.html
Consultative Group on International Agricultural Research (CGIAR)	http://www.cgiar.org
CIESEN Gateway	http://www.ciesin.org/
Clearing House Mechanism (CHM)	http://www.bdt.org.br/bin21/wks95.chm_doc.html
Convention on Biological Diversity (CBD)	http://www.unep.ch/biodiv.html
Convention on Biological Diversity (CBD)	gopher://kaos.erin.gov.au:70/0./biodiv.convention.txt
Convention on International Trade in Endangered Species (CITES)	http://www.erin.gov.au/life/end_vuln/cites.html
Convention on International Trade in Endangered Species (CITES)	http://www.glunet.se/~junior/open/cites.html
Convention on International Trade in Endangered Species (CITES)	http://www.wcmc.org.uk/convent/cites/cn_cites.html
Crocodile Specialist Group	http://www.flmnh.ufl.edu/docs/departments/crocs.htm
Desertification Information Network	http://www.wcmc.org.uk/~dynamic/desert
Disappearing amphibians	http://www.cs.yale.edu/HTML/YALE/CS/HyPlans/loosemore-sandra/froggy/frogs-disappear.txt
Earth's Environmental Experts Ltd	http://www.nhbs.co.uk/3e/
ECNC WWW server	http://www.ecnc.nl/lynx/lynxhome.html
Eco-Compass	http://www.islandpress.com
EcoNet Biodiversity Information Resources	http://www.igc.apc.org/igc/biodiv.html
EcoNet Endangered Species Resources	http://www.igc.apc.org/endangered/
Endangered Bats	http://straylight.tamu.edu/bene/lg/endangered_bats.html
Endangered Species of the U.S. (USFWS)	http://www.ecology.com/endanger.htm
Endangered Species: Images and Natural History	http://nceet.snre.umich.edu/EndSpp/ES.bio.html
Environmental Resources Information Network (ERIN)	http://www.erin.gov.au/erin.html
Environmental Sites on the Internet	http://www.lib.kth.se/~lg/envsite.htm
EnviroWeb—A Project of the EnviroLink Network	http://envirolink.org/
European Centre for Nature Conservation	http://www.ecnc.nl
European Environment Agency	http://www.eea.dk

contd

Table I. *contd*

Organization	URL
Expert Center for Taxonomic Identification (ETI)	http://wwweti.eti.bio.uva.nl/
Extinct, Endangered, and Threatened Plants	http://conbio.bio.uci.edu/at/endangered_plants.htm
FAO	http://www.fao.org
FINS, the Fish Information Service	http://www.actwin.com/fish/index.html
FireNet	http://online.anu.edu.au/Forestry/fire/firenet.html
FROGLOG	http://acsinfo.open.ac.uk/info/newsletters/FROGLOG.html
G7 Environment and Natural Resources Management prototype	http://enrm.ceo.org/
Global Action and Information Network (GAIN)	http://www.igc.apc.org/gain/
Global Conservation	http://gopher.fs.fed.us:70/1/global
Great American Fish Count	http://www.rain.org/~cinms/gafc.html
ICIPE Arthropod Biodiversity Projects Database	http://www.icipe.cgnet.com
ICPPGR	http://icppgr.fao.org
Information Center for the Environment (ICE)	http://ice.ucdavis.edu/environmental_protection/
International Whaling Commission (IWC)	http://www.envirolink.org/orgs/seashep/wh/iwc/iwcmain.html
IUCN—The World Conservation Union	http://w3.iprolink.ch/iucnlib/
IUCN Biodiversity Program	http://www.ciesin.org/IC/iucn/Highlights.html
IUCN Cat Specialist Group	http://www.cathouse-fcc.org/iucn.html
IUCN Red List of Threatened Animals (searchable database)	http://www.wcmc.org.uk/data/database/rl_anml_combo.html
IUCN/SSC Marine Turtle Specialist Group	http://nervm.nerdc.ufl.edu/~accstr/mtsg.html
Man And the Biosphere (MAB)	http://ice.ucdavis.edu/MAB/
Missouri Botanical Garden	http://www.mobot.org/
NASA Landsat Pathfinder Humid Tropical Forest Inventory Project	http://pathfinder-www.sr.unh.edu/pathfinder/index.html
National Biological Service (NBS)	http://www.its.nbs.gov/nbs/
National Park Service	http://www.nps.gov/
National Wildlife Federation	http://www.igc.apc.org/nwf/
Natural History Book Service	http://www.nhbs.co.uk
Natural History Museum, London	http://www.nhm.ac.uk
Natural History Web (Smithsonian Institution)	http://nmnhwww.si.edu
Natural Resources in the National Park System	http://www.nps.gov/nature.html
Policy Instruments Database (PIDB)	http://sedac.ciesin.org/pidb/pidb-home.html
Protected Areas Virtual Library	http://www.wcmc.org.uk/~dyamic/pavl
Rare Plants of Canada	gopher://freenet.victoria.bc.ca/7waissrc%3a/.WAIS/rare/Rare%20Species.src
RouteNet Environmental	http://www.csa.com/routenet/
Royal Botanic Gardens Kew	http://www.rbgkew.org.uk
SIN on Ecological Networks	http://www.ecnc.nl/lynx/lynxhome.html
Species 2000	http://www.uel.ac.uk/species2000/pr_gmsd.html

contd

Table 1. *contd*

Organization	URL
Threatened Plants of the World —IUCN Red List	http://www.wcmc.org.uk/data/database/ rl_plt_combo.html
Tree of Life	http://phylogeny.arizona.edu/tree/ phylogeny.html
Tropical Forests Digital Map Database	http://www.wcmc.org.uk/data/maps/ hb_for.html
U.S. Federal Geographic Data Committee	http://fgdc.er.usgs.gov/
U.S. Fish and Wildlife Service Home Page	http://www.fws.gov/
U.S. National Park Service (NPS), Park List	http://ice.ucdavis.edu/US_National_Park_ Service/NPS_park_list.html
U.S. Natural Heritage Programs	http://www.abi.org/nhp/us/usmap.html
UNEP	http://www.unep.org
UNEP/GRID Metadata Dictionary	http://www.inpe.br/grid/home
UNESCO	http://www.unesco.org
United Nations List of National Parks and Protected Areas	http://www.wcmc.org.uk/infoserv/parks/ cnppa.html
USDA Forest Service	http://www.fs.fed.us/
Wildlife Monographs	http://www.nr.usu.edu/gap/wm.html
Wildlife Preservation Trust	http://www.columbia.edu/cu/cerc/wpti.html
World Conservation Monitoring Centre	http://www.wcmc.org.uk
World Heritage Information Network	http://www.wcmc.org.uk/whin/index1.html
World Resources Institute	http://www.wri.org
WWF	http://www.panda.org/home.html
WWW Virtual Library	http://www.w3.oprg/vl/
WWW Virtual Library: Biodiversity, Ecology, and the Environment (Biosciences)	http://conbio.bio.uic.edu/link/
WWW Virtual Library: Forestry	http://www.metla.fi/info/vlib/Forestry.html

Table 2. Searches for sites with key words 'biodiversity' and 'biological diversity' on Internet, using key search engines, 23 July, 1996.

Search Engine	WWW: 'biodiversity'	Usenet: 'biodiversity'	WWW: 'biological diversity'[1]	WWW: 'biological + diversity'[2]
AltaVista	73999	232	'about 9000'	'about 9000'
excite!	61143	—	44578	723383
InfoSeek	2655	18	467	0
Lycos	10247	—	—	53826
Magellan	4446	—	[3]53300	—
Web Crawler	1199	—	227	14073
Yahoo	47	—	—	5

[1] Search for character string exactly as 'biological diversity'.
[2] Search for sites with combination of both 'biological' and 'diversity'.
[3] Six of these carry reviews.

Peter Schei, chairman of the CBD Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA), emphasized the need for information filters so that decision makers could find the information that they require and trust it. Reliable, comprehensive and up-to-date 'roadmaps' are therefore needed to guide those seeking information. A number of such 'meta-index' or 'virtual library' sites exist on the net,

and the Clearing House Mechanism (CHM), foreseen as a tool in implementing the CBD, aims to solve some of these problems (although there is still debate as to quite how it will do this in practice).

The challenge before the biodiversity information community is to solve the problems of access to relevant information, whether to commercial or non-commercial sources, and to ensure that the information necessary for effective policy setting, management and research is available in the right form to those who need it. This paper cannot hope to review all existing facilities on biodiversity information on the Internet, nor chart a comprehensive course forward. However, we hope it can provide some useful pointers to the directions in which we should all be moving.

INFORMATION RESOURCES

As is discussed by Olivieri, Busby & Harrison (1995) in the *Global Biodiversity Assessment*, organizations throughout the world are discovering the new opportunities provided by improved information technology and the development of communications networks. These opportunities are being increasingly employed by organizations whose aims range from the altruistic to the commercial, and from marketing to advocacy.

International organizations

Many international organizations now provide World-Wide-Web (WWW) sites that describe their programmes and activities. Many parts of the UN system are now accessible through the Internet, including the Food and Agriculture Organization (FAO, http://www.fao.org), the United Nations Educational, Scientific and Cultural Organization (UNESCO, http://www.unesco.org) and the United Nations Environment Programme (UNEP, http://www.unep.org). Convention secretariats such as the Convention on Migratory Species (http://www.wcmc.org.uk/~cms), the Convention on Biological Diversity (http://www.cbd.org, http://www.unep.ch/biodiv.html), and the various parts of the CGIAR network (http://www.cgiar.org) are also present. Several of the WWF organizations have WWW sites (for example http://www.panda.org/home.html), as well as The World Conservation Union (IUCN, http://w3.iprolink.ch/iucnlib/), the World Resources Institute (WRI, http://www.wri.org) and the World

Conservation Monitoring Centre (WCMC, http://www.wcmc.org.uk). Regional organizations such as the European Environment Agency (EEA, http://www.eea.dk) and the European Centre for Nature Conservation (ECNC, http://www.ecnc.nl) also provide a range of information facilities. The International Institute for Sustainable Development (IISD) provides a large number of documents via their WWW pages called 'linkages' (http://www.iisd.ca/linkages/biodiv.html), for example on the decisions taken at the Conferences of the Parties (COP) to the CBD. Many of these are also in word processed and in Adobe Acrobat® form, for example the documents on SBSTTA to the CBD, e.g. the 'Role of the clearing-house mechanism in facilitating and promoting technical and scientific co-operation in research and development' (http://www.iisd.ca/linkages/biodiv/sbstta/sb209.html).

National organizations

Good examples of such developments in the field of biodiversity are the Australian Environmental Resources Information Network (ERIN, http://www.erin.gov.au/erin.html), the Base de Dados Tropical (BDT, http://www.bdt.org.br) in Brazil, and the Biodiversity and Ecosystems Network (BENE, http://straylight.tamu.edu/bene.html) in the USA. Each of these three information servers provides a range of national (and international) information in a variety of formats (though mainly text and graphics), and links to a range of related sites. The ERIN site is a particularly good example of a national information service, set up by Federal Government to facilitate access to information from across Australia. ERIN's programme covers a range of key issues in information management, including information harmonization, development of exchange agreements, and setting clear policies on reponsibility for information. As well as housing a large number of national databases, the BDT collaborates closely with the CBD secretariat in Montreal and a number of other organizations, including the commercial publishers Bioline (http://www.bdt.org/bioline/).

Commercial information

Most commercial and not-for-profit publishers have details of their information products, both print based (books, journals, reference literature) and electronic (software, databases, CD-ROMs), available on the

net as searchable catalogues, some of them including sample chapters or sample data. 'Virtual bookshops', e.g. the Natural History Book Service (http://www.nhbs.co.uk) not only provide a way of purchasing literature but are a useful bibliographic information resource. The NHBS has also recently launched a database of environmental expertise in association with 3E (Earth's Environmental Experts Ltd) (http://www.nhbs.co.uk/3e/), which is free to the user to identify consultants, many of them experts in biodiversity, and paid for by consultants paying for their data to be included on the system.

Primary biodiversity literature is also being published via the net as well as in print based form. Commercial journals publishers have been using Adobe Acrobat® (.pdf) files to deliver facsimiles of the printed word (see for example the journal *Biodiversity and Conservation* (http://www.thomsonscience.com/bc/). Software that allows email comments to be posted about the issues raised in the journal articles is also being experimented with, facilitating an interactive mechanism for individuals to communicate information in a 'virtual community'. See for example http://www.thomson.com/routledge/cst/ross.html or http://www.thomson.com/routledge/cst/liversid.html. The International Council for Scientific Unions (ICSU), who held a meeting on the future of electronic publishing in Paris 19–23 February 1996 have also placed documents on the deliberations of the meeting on a system to allow discussion of the papers (http://www.thomson.com:8866/icsu/Information/Proc_0296/index. html) (see also Shaw & Moore, 1996).

There has also been significant investment by some commercial firms, for example Thomson Technology Labs, in developing 'virtual community systems', using audio-visual software for 'virtual conferences', including slide sequences, real time audio and facilities to be able to draw on screen using a 'whiteboard' (http://ttis.thomtech.com/virtual/vcindex.htm).

RouteNet Environmental (http://www.csa.com/routenet/), built by Cambridge Scientific Abstracts, is a facility with links to significant sites on the net by a team of reviewers, 'discussion rooms', a directory of experts, and other facilities, based around their secondary literature abstracting services.

Chapman and Hall have built a resource centre for biodiversity (http://www.biodiv.com/biodiv.html) with links to significant biodiversity information sites. The links to biodiversity information in this site have brief reviews, so that the user knows a little of what to expect when visiting a particular site.

Universities

A number of universities supply substantial amounts of information on biodiversity (for example, Harvard Biolabs and University of California at Irvine—see below). Some have developed information services based on their programmes. For example, scientists at the University of California, Davis have created the Information Center for the Environment (http://ice.ucdavis.edu). some are providing information for teaching, such as distance learning material and related course-oriented information. For example, The Animal Diversity Database at the University of Michigan (http://www.oit.itd.umich.edu/bio108/) has a large collection of images and sound archives in a phylogenetic structure, which teaches basic skills in ecology and evolution.

A similar phylogenetically structured project called the 'Tree of Life' is at the University of Arizona (http://phylogeny.arizona.edu/tree/phylogeny.html). Its goals are:

> to provide a uniform and linked framework in which to publish electronically information about the evolutionary history and characteristics of all groups of organisms; to present a modern scientific view of the evolutionary tree that unites all organisms on Earth; to aid education about and appreciation of biological diversity; to provide (eventually) a life-wide data base and searching system about characteristics of organisms; and to provide a means to find taxon-specific information on the Internet, both taxonomic and otherwise.

Other non-government organizations

Several NGO sites provide a large amount of information. For example, Missouri Botanical Garden (http://www.mobot.org), The Royal Botanic Gardens Kew (http://www.rbgkew.org.uk) and the Natural History Museum of London (http://www.nhm.ac.uk). The objective of each of these sites is closely linked to the objectives of the institution that sponsored it, and so are useful in assessing the institution's information provision capability. The Missouri Botanical Garden site has open access to its extensive VAST (VAScular Tropicos) nomenclatural database and associated plant name authority database, with over 750,000 scientific plant names. The Expert Center for Taxonomic Identification (ETI), a UNESCO-associated non-profit foundation, publishes taxonomic information on

interactive CD-ROMs and is shortly to sponsor an online World Biodiversity Database (http://wwweti.eti.bio.uva.nl/).

TOOLS FOR INCREASING ACCESS TO INFORMATION

There are now well over 60,000 WWW sites (and increasing) that mention 'biodiversity' or 'biological diversity' (see Table 2).

However, the majority of these simply mention biodiversity without necessarily providing useful information. (Presumably because the word 'biodiversity' is so politically important, especially since the Earth Summit in 1992, one commercial site has registered the word simply to attract people to their site but without providing any biodiversity information!) With biodiversity information on the Internet increasing so rapidly, it is difficult even for those familiar with most of the resources to maintain their knowledge of what is available. However, there exist various mechanisms for keeping up-to-date, including search engines, intelligent agents, mailing lists, email digests, newsgroups, virtual libraries, Special Interest Networks (SINs) and metadatabases, which are reviewed below.

Search engines and intelligent agents

There are many easily accessible 'search engines' (such as AltaVista, excite! and Yahoo), which locate information sources based on user-defined words and phrases (see Table 2). Whilst useful, such global indexing systems are time consuming and rather crude tools to find useful sites, although they are valuable tools to search for at least the most significant sources of information on internet. A number of systems are being developed based on 'neural nets' and 'fuzzy logic' which can act as adjuncts to search engines or can act off-line. These allow the user to construct a query which is then used by the intelligent agent software to search for context sensitive information, based on neural network pattern recognition which processes information in an analogous way to the human brain, learning from mistakes and correcting them, thus increasing in their usefulness as they are used. Examples of these systems are AutoNomy (http://www.agentware.com), 'More Like This' (http://www.morelikethis.com) and Folio Web Retriever (http://www.folio.com)—see also the intelligent agents'

site at Massachusetts Institute of Technology (http://agents.www.media.mit.edu/groups/agents). Using such tools, more specific subject-oriented systems are being built that can identify useful sites on biodiversity (see below). Personalized news services and other services are being developed by organizations such as Agents, Inc. working with Yahoo (http://www.agents-inc.com), and *The Times* (http://www.the-times.co.uk). These systems could be extended to biodiversity information but the authors are not aware of any plans to do so yet.

Newsletters, email digests and discussion lists

Email digests and newsletters can be subscribed to by sending an email message to a computer 'server' which then instructs the server to send regular emails. Examples of these in biodiversity are:

- Biodiversity and Ecosystems Network (BENE). To subscribe, send email 'subscribe BENE FirstName LastName your_email_address' to listproc @straylight.tamu.edu;
- BIODIV-L. To subscribe, send email 'sub BIODIV-L your_name' to listserv@bdt.ftpt.br;
- CONSLINK. To subscribe, send email 'sub CONSLINK your_name' to listserv@sivm.si.edu.

Such discussion lists also provide searchable archives of postings.

An example of a monthly newsletter is Eco-Compass, a WWW newsletter listing and describing environmental internet sites of interest on a particular topic. This is provided free as a public service to the online community by Island Press, a not-for-profit publisher (http://www.islandpress.com/Eco-Compass/ECOCOMPHOME.HTM). It can also be subscribed to directly by email (to subscribe, email 'subscribe islandpress-L' to Majordomo@igc.apc.org).

Virtual libraries

Some 'virtual libraries' have been built to help with the problem of finding relevant information. A virtual library is an organized set of links to items (documents, software, images, databases) resident in different computers on the networks. The purpose of a virtual library is to enable users to find information that exists elsewhere on the network from one central ('virtual') location.

At its simplest, a virtual library is a series of

'bookmarks' set up by someone to assist location of sites that they think useful or interesting. For example the ERIN WWW server includes an excellent facility for locating other WWW sites of interest using keyword searches. The ECNC WWW server (http://www. ecnc.nl/) provides links to a wide range of other European WWW servers for organizations working on nature conservation. A range of other organizations, including commercial organizations, are providing lists of key WWW sites, the more useful of which are those that are comprehensive and/or those that are providing annotated links. Examples are RouteNet Environmental (http://www.csa.com/routenet/), and Chapman & Hall's Biodiversity Resource Center (http://www.biodiv.com).

Virtual libraries are probably most effective when set up in fairly well-defined areas or organizations working in those areas, for example, the protected areas virtual library (http://www.wcmc.org.uk/ ~dynamic/pavl) set up by the WCMC.

The World Wide Web Consortium holds the WWW Virtual Library (http://www.w3.org/vl/). This is a distributed subject catalogue and includes a list of virtual libraries in a number of fields including those of interest to biodiversity. Specialist organizations working in the field of biodiversity have established a range of valuable virtual libraries including 'BioSciences' (until recently housed at Harvard University in the United States = http://golgi. harvard.edu/biopages.html, but now moved to University of California at Irvine 'Biodiversity, Ecology and the Environment' = http://conbio.bio.uci.edu/link) and 'Forestry' (http://www.metla.fi/info/vlib/Forestry. html), among many others. All of these are part of the distributed WWW Virtual Library, and all serve a valuable purpose in helping users to locate potentially useful WWW pages. The site at the University of California at Irvine, in particular, has a well-ordered and comprehensive site, although it only supplies links without an explanation of what will be found when going to the site to which it is linked.

The G7 Environment and Natural Resources Management prototype (http://enrm.ceo.org/) is a global virtual distributed library with free online registration and interactive editing of the records held on environmental information. It is sponsored by the G7 nations, together with such organizations as the European Environment Agency, ERIN, NASA, UNEP and others. A search on 23 July 1996 for 'biodiversity' on this prototype yielded information on 103 internet sites, but this number is growing rapidly.

Special interest networks

A Special Interest Network (SIN) is a group of people and/or institutions who collaborate to provide information about a particular subject and they usually consist of a series of participating 'nodes' that contribute to the network's funtions (Green & Croft, 1994). SINs are almost the modern equivalent of learned societies, performing such functions such as publication (journals, newsletters, datasets, software), library services (links to both onsite and offsite sources), communication (mailing lists, workshops and conferences), and other services (specialist advice, data analysis). The theory of SINs is discussed by Green (1994).

Various projects are putting the SIN concept into practice. For example, FireNet (http://online.anu. edu.au/Forestry/fire/firenet.html) is concerned with all aspects of landscape fires (Green & Croft, 1994). The Biodiversity Information Network BIN21 (http:// www.bdt.org.br/bin21/bin21.html) has developed through affiliations and network links between organizations that are already carrying out related activities (Canhos et al., 1992). The newly established SIN on Ecological Networks (http://www.ecnc.nl/lynx/lynxhome.html) aims to share information necessary for establishment and management of the Pan European Ecological Network.

Metadatabases

Metadatabases provide information on what information is available where, using structured descriptions of the available datasets. Good examples of metadatabases available over the Internet are the UNEP/ GRID Metadata Dictionary which was set up as a system of 'cooperating centres within the United Nations Environment Programme (UNEP) that is dedicated to making environmental information more readily accessible to environmental analysts as well as international and national decision makers' (quoted from http://www.inpe.br/grid/home). The GRID-INPE WWW service's mission 'is to provide timely and reliable georeferenced environmental information. Besides acquiring and disseminating integrated, spatially-referenced environmental data, GRID provides decision-support services to environmental analysts and international and national decision makers, and fosters the use of geographic information systems (GIS) and satellite image processing (IP) as tools for environmental analysis'.

Similarly, the U.S. Federal Geographic Data Committee, chaired by the biologist Bruce Babbitt, US Secretary of State for the Interior, provides improved access to geospatial data by the use of common data standards (http://fgdc.er.usgs.gov/).

The Consortium for International Earth Science Information Network (CIESIN) have built a Gateway which 'facilitates access to data and information on human interactions in the environment, global environmental change, and sustainable development'. It 'provides access to a distributed catalog that identifies data and information resources relevant to these topics. The Gateway is unique in that it conducts simultaneous search and retrieval across diverse databases worldwide' (quotes from the site at http://wwwgateway.ciesin.org).

Information services

Several organizations are using a combination of these mechanisms to provide information services both to their own collaborators and to other interested organizations and individuals. Three examples will be given.

IOPI. The International Organization for Plant Information (IOPI), a commission of the International Union of Biological Sciences (IUBS), was set up in 1991 to coordinate the creation of plant taxonomic databases. The idea is to establish a Global Plant Species Information System (GPSIS). The site on the net, housed at the Charles Sturt University in Australia (http://iopi.csu.edu.au/iopi/iopihome.html) has a Database of Plant Databases (DPD), which points to taxonomic databases, collections catalogues and DELTA (Description Language for Taxonomy) datasets.

Species 2000. Similarly, the Species 2000 project (http://www.uel.ac.uk/species2000/pr_gmsd.html) is a system that links together all sites with species information, with a search engine that searches across a species index with agreed data standards. It has the 'objective of enumerating all known species of plants, animals, fungi and microbes on Earth as the baseline dataset for studies of global biodiversity' (quote from a brochure). This serves as a response to the call by May and others to develop a database of known species diversity (May, 1988; Stork, 1993). The species names are supplied by taxonomic experts, allowing users to verify the scientific name, status and classification of any known species.

WHIN. The World Heritage Information Network

(WHIN) (http://www.wcmc.org.uk/whin/index1.html) exists as a focal point for finding information across an array of WWW pages run by different organizations, set up by the WCMC with ICOMOS and the World Heritage Centre. This uses Harvest search software to supply links to information held elsewhere on the net. For example one can search for the Río Plátano Biosphere reserve in Honduras with this system, which then gives hyperlinks to archive information on the UNESCO site about the reserve.

FUTURE DIRECTIONS

Data and information on the status of the world's biodiversity is urgently needed. At the international, national and community levels, decisions are being taken that affect our environment yet biodiversity information critical to such decisions is frequently absent. The reason is simple: no global source for such data exists owing to the enormous human, financial and technical resources required. The developing Clearing House Mechanism (CHM), and the proposed Biodiversity Conservation Information System (BCIS) are discussed here as part of the way forward, increasing accessibility to information.

Biodiversity Conservation Information System (BCIS)

Nine international conservation organizations and networks, comprising thousands of scientists, resources managers, educators and legal experts, have joined forces to tackle the challenge. Spearheaded by IUCN–The World Conservation Union, the Biodiversity Conservation Information System (BCIS) provides a new approach that links the expertise and data held within key conservation organizations with the dissemination potential of emerging information and communication technology. BCIS is seen as a decentralized information gathering, exchange and dissemination system dedicated to the conservation of biodiversity, landscapes and aquatic environments (see Fig. 1.).

BCIS will support data collection and management at the ground level. The rights and interests of these 'data custodians' will be both protected and supported by the global network. Equally important are the benefits to all levels: BCIS will provide:

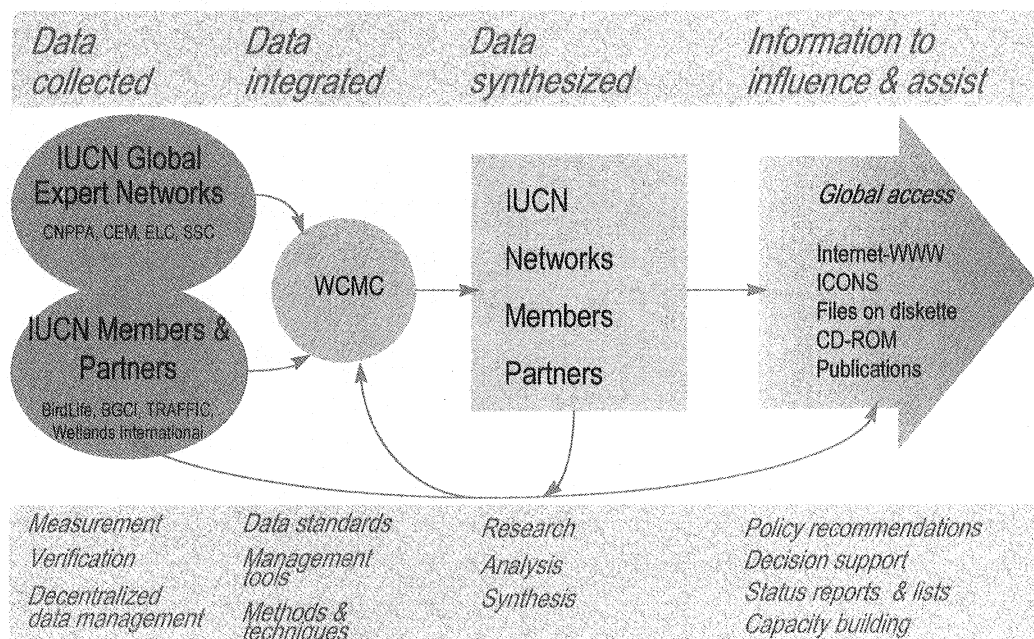● improved access between and amongst data custodians;

Fig. I. Flow diagram of proposed Biodiversity Conservation Information System.

● mechanisms for peer review, quality control and validation;
● tools for integrating textual, numeric and spatial data; and
● enhanced delivery and dissemination mechanisms.

These benefits will increase both the volume and the quality of biodiversity data available to those concerned with biodiversity, from primary researchers and users to decision makers at the international level.

BCIS is intended to directly benefit conservation by providing governments, international institutions and non-governmental organizations (NGOs) rapid access to information upon which to base environmentally sound decisions. One of the best ways of providing access to such information resources is over the internet.

Clearing house mechanism

The Convention on Biological Diversity (CBD) in a number of its Articles requires or implies the need for facilities for the management and open exchange of biodiversity information. Articles 7d, 12c, 13b, 15(7) and 16, each identify information management and exchange requirements, and Article 17 explicitly indicates 'access to and transfer of technology among Contracting Parties are essential elements for the attainment of the objectives of this Convention'. Article 18(3), requires the establishment of 'a clearing house mechanism to promote and facilitate technical and scientific cooperation'. Some central focus through which exchange of information can take place is clearly both highly desirable for, and explicitly required by, the Convention.

During the consultation process led by the CBD Secretariat, a number of practical considerations have also evolved, and have been reflected in Secretariat documents:

● access to the CHM should be as open as possible, with provisions for nations with limited information technology infrastructure;
● the CHM should avoid duplicating services provided by existing centres and networks;
● the CHM should be a 'clearing house of clearing

houses', or switching centre, and should not hold or maintain large databases;

- the CHM should link with national, sub-regional and regional centres of information;
- operations of the CHM should be efficient and transparent and subject to the review of the Conference of Parties;
- the CHM must respect the intellectual property rights of public and private sector participants.

Discussion on the CHM is continuing, and various prototypes have been developed (see http://www.wcmc.org.uk/~dynamic/chm/ and http://www.istar.ca/biodiv/). It is hoped that further meetings will help clarify the direction being taken and how the facility will be developed in the future. Whatever decisions are taken, the Internet will be a significant part of future information dissemination, and access to biodiversity information will be increased.

CONCLUSION

Clearly the internet provides valuable mechanisms for delivery and receipt of apposite information by researchers, policy decision makers and students in biodiversity. However, to achieve its full potential will require much more effort to be put into improved mechanisms for locating appropriate information of known quality that meet user needs. This requires strategic planning and vision on the part of those developing information services. The BCIS and the CHM, and the building of commercial systems, are mechanisms for increasing access to specialist and focused information. The issues now are not technical—they are to do with cooperation and collaboration.

Note added in proof: since this paper was submitted towards the end of 1996, some of the web sites mentioned may have moved or no longer exist. We suggest that you use the search engines or up-to-date biodiversity 'resource centres' to locate those that may have moved.

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