8

Biodiversity mapping and modelling

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8.1 CONTEXT

The current global decline and loss of biological diversity (biodiversity) is now a major public-policy issue, with a number of international conventions focussing specifically on biodiversity, e.g. *The Convention on Biological Diversity* (CBD), *Convention on International Trade in Endangered Species of Wild Fauna and Flora* (CITES), *Convention on Migratory Species* (Bonn Convention) and *The Ramsar Convention on Wetlands* (see References). Contracting Parties to these conventions, generally nation states, are obligated to report on the status of, and trends in, biodiversity, within their respective jurisdictions.

Increasingly, countries are also recognizing that biodiversity issues are not contained within national borders, so regional initiatives are also under way, such as the *Agreement on the Conservation of Bats in Europe* (EUROBATS 1991). Some 33 international agreements related to the conservation of biological diversity are currently listed in the Environmental Treaties and Resource Indicators (ENTRI) system (CIESIN 1998).

Biodiversity mapping and modelling is becoming increasingly important to the successful implementation of these initiatives, not only to the governments and intergovernmental agencies and programmes directly involved, but also at local levels including individuals and community groups, as well as indigenous peoples.

Agencies and individuals involved in the assessment and management of living resources at all geographic scales need the insights provided by scientific research on the nature and distribution of biodiversity. This chapter focuses on the mobilization of spatial data, as well as the use of tools and techniques to generate information from these spatial data, that informs various stakeholder groups on the many dimensions of biodiversity.

8.2 DEFINITIONS

Article 2 of the *Convention on Biological Diversity* specifies the following 'Use of Terms' for the purposes of the Convention:

- **'Biological diversity'** means the variability among living organisms from all sources including, *inter alia*, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems.
- **'Ecosystem'** means a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit.

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8.3 KEY ISSUES

There are fundamental challenges in translating the above definitions into operational programs. These centre around the question 'What is a high biodiversity value?'. For example, a high biodiversity value may be attached to a group (e.g. family) in which a large number of species have been described, yet a single species in an isolated region may possess more genetic diversity than these combined species. Similarly species-rich ecosystems, such as tropical rainforests, tend to attract more attention than species-poor ecosystems occurring in harsher environments, such as arid and semi-arid regions. However the latter species may be of very high evolutionary, ecological, social or economic value. All these issues need to be balanced when scarce resources are being allocated. The key point here is that the value of the answer depends very much on the question being asked. The challenge is to ask the right question, such as 'what is a high biological diversity value?'.

Any framework for biodiversity mapping and modelling must, *inter alia,* bridge the gap between science-based data on the nature and distribution of biological diversity and knowledge that is relevant to people, in particular policy makers and decision takers. The following questions exemplify this transition, going from reasonably straightforward baseline inventory to complex scenario building, whereby a resource manager can not only explore various options for action in the field but also provide policy-relevant advice to executive management:

- what are the various elements of biodiversity?
- where does something (species, ecosystem) occur?
- what (species of interest, some environmental resource) is found in a particular place (protected area, administrative zone)?
- what (environments, ecosystems, some environmental resource) exist and where are they found?
- how are environments being managed?
- is something (species, ecosystem, some environmental resource) changing, by how much, is it important, what can be done about it?
- what will happen if a perturbation (fire, global warming, agricultural activity etc.) is made to the ecosystem?

Note that the scientific issues that dominate the earlier questions are progressively counterbalanced by social and economic issues in later ones. Many tools have been developed and much data have been collected in attempts to answer these questions. Regrettably, invalid assumptions, inadequate or inaccurate data and flawed procedures have rendered many of these efforts little more than 'computer games', of very little practical benefit to the assessment and management of living resources.

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8.4 MOBILIZING THE DATA

Contrary to popular belief, there are masses of data 'out there'. They are scattered, incomplete, of variable quality and poorly documented. In too many cases, it has proven cost-effective to collect new data rather than to attempt to collate and upgrade existing data (See also Chapter 3 and 4).

8.4.1 Attribute selection

The first decision in mobilizing the data is about what data to collect. The attribute selection prior to data collection will dominate future options for modelling and interpretation. Attributes can be 'factual' or 'primary' or, alternatively, 'derived' or 'classified'. Examples of primary attributes include latitude and longitude of the place where an observation was made, date of that observation, height of a tree, or mean annual temperature of a site. These data can all be measured or otherwise described against a stable, objective or widely accepted standard.

People are, however, uncomfortable with working with raw, unprocessed data. They instinctively like to classify data into categories that have greater meaning to them. Such derived attributes are those developed from primary attributes through a process of interpretation or classification applied at the time, or subsequently, according to some paradigm. These include: species name, soil type, vegetation class, climate zone.

The difficulty is that these classified categories are erected for a specific purpose and are not necessarily widely shared or understood. Thus other people may have great difficulty in understanding what these categories mean. In general, therefore, derived attributes should not be recorded in a database unless the primary attributes from which they were derived are also available. This is because, as concepts and paradigms change, derived data degrade in value and may even become useless. For example, if the only representation of a species distribution is a map stored as a polygon coverage in a geographic information system (GIS), this distribution is valueless if that species is split following a taxonomic revision. Examples of primary and derived attributes are shown in Table 8.1.

Table 8.1: Examples of primary vs. derived attributes.

Primary	Derived
Geocode (i.e. a point reference such as latitude and longitude)	Grid cells (e.g. 1 km grids), administrative zones (e.g. counties)
Plant height in absolute units, e.g. metres	Plant height as 'tall', 'medium' or 'low'
Actual time of observation	'Early morning', 'dusk'
Actual date Start and end dates of observation	'Summer'
Mean annual temperature	'Hot'

A particularly difficult example is species name, a derived attribute for which there is no feasible alternative. Most researchers have no option but to use species names (where there is one), even though these change from time to time. It is simply not

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practicable to store all the myriad primary attributes of an organism so that it can be unambiguously allocated to a taxon whenever its group is revised.

The principle is clear: we need to minimise the risk of datasets becoming obsolete as a result of changing concepts and classifications.

8.4.2 Sampling design

The way in which records are made in the field fundamentally determines the potential use for the data. Decisions made about sampling strategies will influence options of which analytical tools can be used.

The selection of a study area is the first important decision. In some cases the problem determines the area, e.g. for a project investigating the distribution of lizard species on a (small) island, the study area is self-evident. However, more commonly, the study area is selected from some larger region. The selection may be made according to some probability sampling scheme, or it may simply reflect the recorder's view that the study area is in some sense representative of the larger region. However it is done, data collection needs to be 'representative' of the environmental feature(s) under investigation in order for the analysis to lead to reliable and useful conclusions. If the data are to be quantitatively analyzed, the statistics may be based on certain assumptions about the sampling scheme, such as sample selection is random and independent. To ensure representativeness, sampling in the field may be stratified (Cochran 1977). Various sampling schemes (e.g., random, stratified random, regular) may be used depending on the issue under consideration, the nature of the environment, logistics, and the proposed analysis tools, and are reviewed in Cochran (1977).

One of the objectives of field data collection is to distinguish patterns in the distribution of biodiversity, identify their possible causes, and predict future behaviour. Thus, biologists are not so much interested in showing that an observed pattern departs significantly from 'complete spatial randomness', as in interpreting and understanding the pattern (Diggle 1983).

8.4.3 Data capture

Ideally, the individual attributes should be recorded in compliance with some standard but, even more importantly, in a consistent way. Where there are competing standards, or no standard that is either available or followed, it is vital to be consistent and to thoroughly document the actions taken in the capture process. It is generally far easier to convert a dataset that is recorded consistently, even though not in compliance with a standard(s), than to convert a dataset that purports to meet a standard, but is inconsistent. A framework for standards applicable to specimens and observations of species collected in the field is shown in Table 8.2. Note that missing (e.g. impossible to measure or absent) attribute values should be indicated as such, rather than the fields just left blank.

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8.4.4 Standards and quality assurance

Data collection is expensive, thus it is important to maximize the use of data. The collection and management of data with multiple uses in mind will bring the highest return on investment. This is aided significantly by the adoption and implementation of standards for recording and managing biodiversity data and by quality-assurance procedures that ensure data meets the required standard(s). An example of standards is given in Table 8.2.

Table 8.2: Indicative attributes and standards for species occurrence records.

Attribute	Standard	Notes
Record class	Type of record	Specimen – should include information on the collection (e.g. museum name or identifier) and collection identifier
		Observation – should include name of observer
		Literature – should include (link to) full bibliographic reference
Taxon name	Taxon authority list	National checklist (e.g. Australia : Census of Australian Vertebrate Species (CAVS) Version 8.1) international list (e.g. Species 2000). May need to include supra- and infra-specific names to provide further context or additional detail, or even broader categories where the taxon cannot be identified with precision
Georeference (geocode)	Latitude and longitude	Universally applicable but needs to be recorded consistently (e.g. degrees, minutes, seconds)
	Map grid reference	Depends on the mapping system and can be very difficult to convert to other systems, such as latitude-longitude. The full reference needs to be recorded, rather than abbreviated ones and full details of the map coordinate system, including origin references, should be recorded
	Customized grid	These are frequently developed to meet particular project objectives (e.g. publication of distribution maps at particular scales), but can be extremely difficult to convert. Often the grids are so large that valuable details of locality are lost
Locality	Named place from gazetteer, often qualified by distance and direction from named place	Name may need to be further qualified if this is not unique, e.g. there are many different 'Sandy Creek's, in the Australian national gazetteer
Date and time	Year/month/day hour:minutes	May need to accommodate ranges for extended observation periods

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[Note that other secondary supporting attributes will also be required, e.g. collector(s) name, identifier(s) name, date of identification, altitude, depth, previous names applied to this record, geographic region (e.g. catchment), administrative region (e.g. county – remember that these boundaries can change over time), qualifiers on any of the above, e.g. geocode precision].

The purpose of standards is to ***minimise the transaction costs of using data.*** They are the means to expedite information communication amongst people, from different disciplines, who examine an environmental issue from different perspectives. Standards cover:

- the selection of attributes representing the environmental feature(s) under investigation
- data collection methods and survey protocols
- the meaning of those attributes (allowable numeric ranges, values, etc.)
- methods of documenting (metadata) and assuring the quality of those attributes: their representation (spatial, tabular, text, etc.), management, security, etc.
- how those attributes are communicated to others via various media.

Standards for generation, management and quality assurance of biodiversity data are very difficult to establish because of the wide variation in species attributes and, consequently, of work practices of institutions that handle them (see Box 8.1). Some examples of standards are listed in Box 8.2.

Box 8.1: Museum collections databases

Extract from *Statement of the Problem* from the Oz Project at the University of Kansas

Unfortunately, there are no standards for computerised collection management. Most institutions have developed unique, in-house solutions to handle their computational needs. Even within the same museum, different collections often use different database designs and database management software. This makes it difficult, if not impossible, to access information simultaneously about the holdings in multiple collections or institutions. This practice is also costly and difficult for an institution to maintain because expertise in many database designs and RDBMS software is needed.

There are many reasons for this situation. The most important is that different disciplines maintain different types of data. For example, the information stored about specimen measurements for a mammal may be completely different than for a fish. Habitat and preparation data are other important examples. In addition, certain types of data may be more important for some collections than it is for others. Entomologists, for instance, are much more concerned with easily changing taxonomic identifications of specimens than ornithologists or mammalogists. This means even when different collections maintain the same kind of data, the systems they use to access the data may differ functionally.

Another cause of divergent functionality is that different collections often use dissimilar management practices. The process of collecting, accessioning, preparing, identifying and cataloguing a specimen in a herpetology collection may be completely different than that for a specimen in an entomology collection, and the software developed for the respective collections often reflects this. Also, collection management systems have mainly been developed to support specimen-based collections. However, there are non-specimen based collection items which need record keeping.

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Box 8.2: Biodiversity standards and protocols (US)

National Survey of Land Cover Mapping Protocols Used in the Gap Analysis Program <http://www.calmit.unl.edu/gapmap/report.htmi>

Methods for Assessing Accuracy of Animal Distribution Maps, Blair Csuti and Patrick Crist <http://www.gap.uidaho.edu/handbook/VertebrateDistributionAssessment/default.htm>

Methods for Developing Terrestrial Vertebrate Distribution Maps for GAP Analysis, Blair Csuti and Patrick Crist
<http://www.gap.uidaho.edu/handbook/vertebrateDistributionModeling/default.htm>

Vegetation Classification Standard, Vegetation Subcommittee, Federal Geographic Data Committee, June 1997 <http:://www.fgdc.gov/standards/documents/standards/vegetation>

8.4.5 Data custodianship and access

Field collection of data is desirable because it is both current and the attributes recorded can be tailored to the purpose of the study. However, for cost and other reasons, this may not always be possible and use must be made of existing data, at least in part. Existing data can be extremely useful in extending or interpolating field observations and, of course, there is little alternative for studies of changes over long periods of time.

The process of finding other data is aided considerably by the progressive development of clearing houses and metadatabases (see examples in References and Chapter 4). Such catalogues can be very useful in locating potentially-useful datasets.

Existing data are, of course, generally managed by others. These 'data custodians' have very varied approaches to data management and equally varied policies and procedures relating to data access. Custodians have a number of specific concerns about releasing data, including:

- will the dataset be used 'correctly'?
- is the exchange consistent with corporate policy?
- will use of the dataset be fully acknowledged?
- could credibility suffer (e.g. where data are found to be of poor quality)?
- will costs be covered?
- is there any vulnerability to legal liability in the event that the data are shown to be incorrect and some harm has resulted?

These concerns are most effectively addressed in a data access agreement between the data custodian and the potential user. Data access agreements can be quite varied, but usually include the following elements:

- permitted/excluded uses
- how/whether to distribute to third parties (normally not permitted)
- how to acknowledge
- details of any transaction costs
- a disclaimer (to protect the custodian from legal liability).

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Normally different provisions (especially transaction costs) vary with the class of user. Scientific and public education uses are generally less restricted than commercial uses, for example. Normally it is strongly advised to fulsomely acknowledge the sources of data used, regardless whether this is a provision of the data access agreement. This builds a level of trust between custodians and users that is essential to the unrestricted flow and multiple use of data.

8.4.6 Data mining and harmonization

Although considerable volumes of data may exist, they are all too often scattered, incomplete and of undocumented quality. Nevertheless, scarce resources can often be cost-effectively employed in extracting data from one or more existing sources ('data mining') and, as necessary, merging them ('data harmonization').

Once a potential dataset has been located, further investigation will determine whether any potentially useful records are present. Once these have been extracted, they will generally need to be 'harmonized' with other records. This process is considerably aided if all the records meet the same or closely related standards or, failing that, if they have been recorded consistently within their home dataset. In the latter case, it is often possible to convert the data to a standard form by automated procedures. Otherwise it can be a very labour-intensive process to convert large number of records on a case-by-case basis.

Of course, once a composite dataset has been laboriously constructed, it is important to document the dataset and the process by which it was built, in order to ensure that the dataset becomes of maximum value to other projects.

8.5 TOOLS AND TECHNIQUES

While collection of large volumes of data is relatively straightforward, these raw data are generally not particularly useful without further analysis and interpretation. Understanding is enhanced when data are converted into information through the application of appropriate tools and techniques. Different kinds of tools are needed for different stages in the 'information manufacturing' process as raw data is progressively converted to useful information products up the 'information pyramid' (Figure 8.1).

There are many tools currently available and more are being developed all the time. These tools vary considerably, not only in the tasks they perform but also in reliability, documentation and support. Tools range from commercial products from major software suppliers, through packages that have been developed and are supported to varying extents by government agencies, scientific institutions and universities, through to those developed by individuals for their own purposes. The last of these vary considerably in quality. They may be very difficult to load and operate, they may be unreliable and they are often poorly documented and unsupported.

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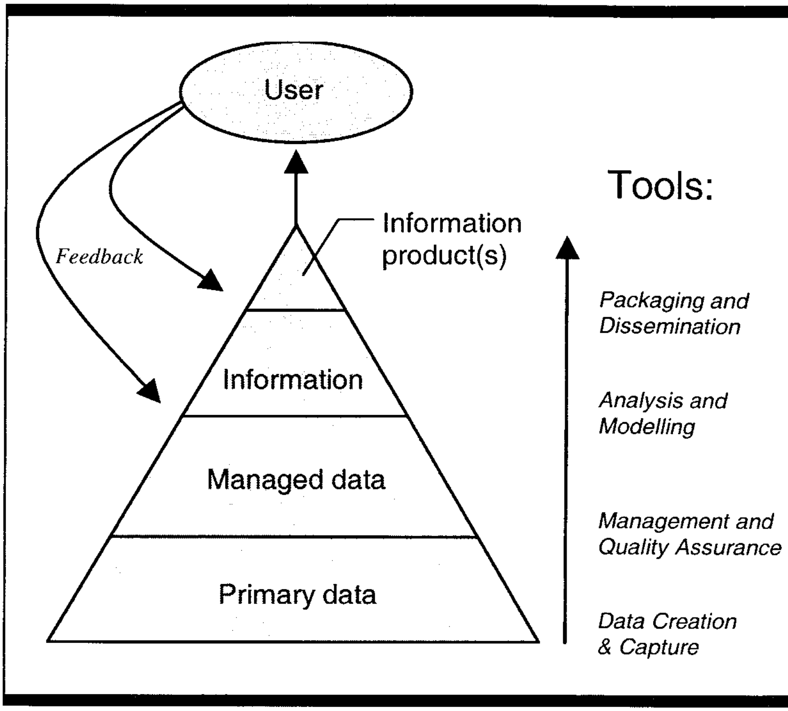

Figure 8.1: Tools to support data flow up the 'information pyramid' (modified from Figure 2 in World Conservation Monitoring Centre (1998a)).

Detailed evaluation of data generation, management and quality assurance tools is beyond the scope of this chapter. However it is important to ensure that correct choices are made among those available in order to expedite analysis and modelling. As indicated above, choices made with data collection and selection will inevitably influence options for analysis and interpretation. All too often, major deficiencies in the data are obscured by subsequent analyses, resulting in maps and other products that, although visually impressive, are very misleading. Worse still, they could even result in the misallocation of scarce resources or unintended environmental outcomes.

It is also vital to understand the audience or intended target for the results. An impressive, but highly complex model will baffle most senior managers and other non-specialists. The data may be impeccable and the science world class, but managers will be very reluctant to accept the results and will seize on almost any excuse to avoid doing so. On the other hand, a very simple analysis may be summarily dismissed as not dealing adequately with the complexity of the 'real world'.

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8.5.1 Database management

Most species occurrence data is managed as sets of 'tables' (files) by 'relational database management systems' (RDBMS). Each table is an 'entity' (such as a species) which possesses a number of 'attributes', such as name, life form, conservation status, etc. These entities are linked by a set of 'relationships', for example a 'species' entity is linked to a 'site' entity by a relationship that a species has been recorded at a site. Entity-Relationship (E-R) diagrams are frequently used to document these. RDBMS software manages the entities and relationships, allowing data entry, updating, searching, sorting and reporting.

Associated with RDBMS has been the progressive development of 'Structured Query Language' (SQL). This is an English-like retrieval language for querying relational databases. SQL is database independent, which frees organizations from being committed to any particular brand of RDBMS. SQL has also benefited from the development of client-server database architectures. Client-server is currently built into most commercial RDBMS packages, which facilitates the development of datasets that can be accessed by a wide range of users in remote locations (Olivieri *et al.* 1995).

8.5.2 Geographic information systems

GIS, and its role in environmental modelling, is covered throughout this book. In the following section, some of the aspects of raster and vector data as they apply to biodiversity data will be outlined.

8.5.2.1 Raster data

Raster data structure is an abstraction of the real world where spatial data are expressed as a matrix of cells or pixels, with spatial position implicit in the ordering of the pixels. With the raster data model, spatial data are not continuous but divided into discrete units. This makes raster data particularly suitable for certain types of spatial operation, for example overlays, area calculations, or simulation modelling, where the various attributes for each pixel can be readily manipulated because they are referenced to a common geographic base. Unlike vector data however, there are no implicit topological relationships. Remote sensing data are largely stored and manipulated in raster form.

With biodiversity data, a raster format can be particularly effective for displaying results, and especially for biodiversity units that cover substantial areas, such as large vegetation units, or modelling predicted distributions of species. A raster format is not recommended for storing input data, unless the pixels are extremely small, i.e. equivalent to points, or otherwise very much smaller than the scale at which analyses will be required. This is because of difficulties in disaggregating data for areas that are subsets of individual pixels or that cross pixel boundaries. In such cases it is uncertain whether or not the pixel attributes apply to the areas under investigation, and the data may therefore be unusable.

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8.5.2.2 Vector data

The vector data structure is an abstraction of the real world where positional data is represented in the form of coordinates. In vector data, the basic units of spatial information are points, lines and polygons. Each of these units is composed simply as a series of one or more coordinate points, for example, a line is a collection of related points, and a polygon is a collection of related lines. Typical vector data include administrative boundaries (polygons), road networks (lines) and sites where rare species have been recorded (points).

Points are commonly used to represent individual records of species, although polygons are also used to represent species distributions and vegetation and environmental units. Comparatively few biodiversity attributes are linear, although some vegetation types, such as mangroves or riparian vegetation, may be quasi-linear, or be represented that way at coarse scales.

As indicated above under *Attribute selection,* polygons should not be used for storing raw data on species distributions because of the difficulties of disaggregating them if identifications change. However they are very effective for display purposes.

8.5.3 Distribution mapping tools

8.5.3.1 Where does a species occur?

Hand-drawn maps or simple GIS are all that is required to answer this question, given appropriate raw data. The same tools can be used to plot the locations of ecosystems. More sophisticated tools can deliver dynamic maps over the Internet. For example the service once provided by Environment Australia prompted for a species name then, once the user had made a selection, initiated a SQL query on a relational database, put the retrieved data through a mapping tool and returned a map with associated metadata (Figure 8.2).

BIOCLIM is one example of a tool that uses environmental parameters, in this case climate, to estimate species distributions (Box 8.3). The above species mapping service provided BIOCLIM predictions on-line.

Box 8.3: BIOCLIM

BIOCLIM can be used to analyse and estimate the distribution of any entity – animal or plant species or vegetation type – that is influenced by climate. BIOCLIM requires climate surfaces that are used to produce site-specific estimates of monthly temperature and precipitation for places where the entity has been recorded. The climate estimates are then aggregated into a 'climate profile' (see Chapter 2), using parameters that are indicative of annual mean, seasonal and monthly extreme values.

Predicted distributions are based on the similarity of climates at points on some geographic grid to the climate profile.

BIOCLIM has been used to model the distributions of a wide variety of organisms, including temperate rainforest trees (Busby 1986), snakes (Longmore 1986), bats (e.g. Walton *et al.* 1992) and brine shrimps (Williams and Busby 1991). It can also reconstruct palaeohistoric distributions (e.g. McKenzie and Busby 1992, Kershaw *et al.* 1994) and predict the potential impacts of climate change (e.g. Busby 1988; Dexter *et al.* 1995).
[Source: Busby (1991)]

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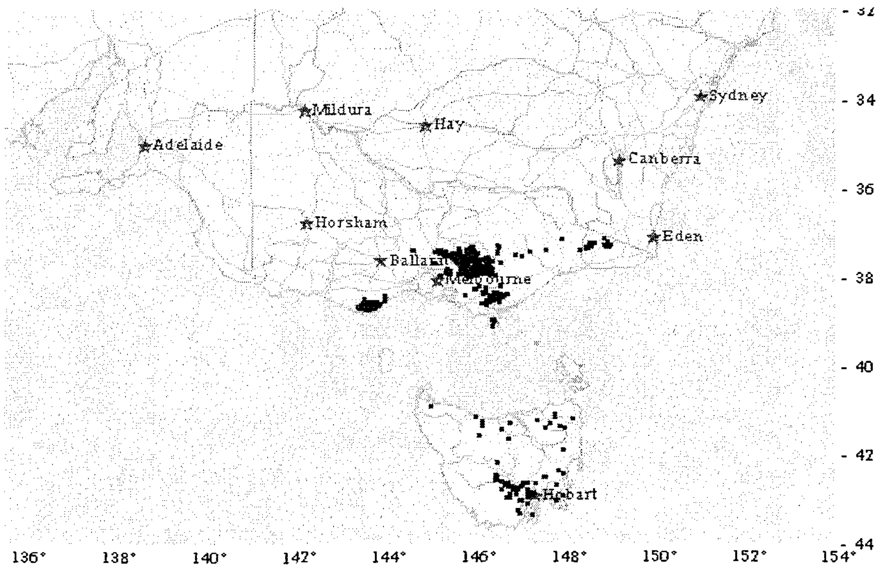

Data Source/ Collection Information for *Eucalyptus regnans*		
Institution	**Collection Dates**	**Number of Records**
Australian National Botanic Gardens Herbarium, Canberra	1969–1983	10
Australian National Herbarium, CSIRO, Canberra	1920–1986	50
CSIRO Tree Seed Centre, Canberra	1962–1989	77
Department of Conservation and Natural Resources, Victoria	1900–1990	1,228
NSW Herbarium, Sydney	1899–1986	40
National Herbarium of Victoria, Melbourne	1867–1991	55
Queensland Herbarium, Brisbane	1955–1976	5
Tasmanian Herbarium, Hobart	1897–1980	51
Total: 1,516		

Figure 8.2: Distribution of *Eucalyptus regnans*, the world's tallest hardwood tree species
***Source*: The data, from the custodians listed above, as in the ERIN database at 25 March 1999. The base map is based on spatial data available from the Australian Surveying and Land Information Group (AUSLIG).**

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8.5.3.2 What is found in a particular place?

The answer to this question is somewhat more complex, depending on how that 'place' is defined relative to the way the data are stored. If the data are stored as layers in a GIS and the place is a defined polygon (or its raster equivalent, if appropriate), then the required layers can be overlaid and the polygon of interest clipped out, a process known as 'cookie cutting'. Similarly, if the place of interest is a defined attribute of data stored in a RDBMS, then a simple retrieval of all records possessing that attribute will achieve the desired result.

On the other hand, if the place is a polygon in a GIS and the data are stored as tables in a relational database, or the data are GIS layers but the place has no defined spatial attributes, then the task can be very difficult.

8.5.4 Environmental domain analysis

8.5.4.1 What environments exist and where are they found?

Classifying a large area into a number of regions that are relatively homogeneous for some set of environmental attributes provides a useful framework for focussing attention, summarizing patterns, aggregating information, and allocating resources and priorities in nature conservation. These regions can be interpreted as vegetation types, ecosystems, landscapes, eco-regions, biomes or environmental domains, depending on the attributes chosen, the map scale, and the objectives of the analysis. Environmental attributes can include climate, lithology/geology, landform, soils, vegetation, flora and fauna, and land use (Box 8.4).

Box 8.4: Interim Biogeographic Regionalization of Australia

The Interim Biogeographic Regionalization of Australia (IBRA) is an integrated classification of both biotic and abiotic variation. IBRA regions represent a landscape-based approach to classifying the land surface, including attributes of climate, geomorphology, landform, lithology, and characteristic flora and fauna. The developers acknowledge that new information will modify our understanding of the regions, hence the term interim (Thackway and Cresswell 1995).

The National Reserves System Cooperative Program (NRSCP) needed a classification of ecosystems agreed by all Australian nature conservation agencies. The IBRA was developed to provide an ecological framework within which to identify gaps in the national reserves system and to set priorities for gap filling.

By itself the IBRA is of little value in assisting decision makers determine gaps and set priorities. The value of IBRA for this purpose lies in the development of conservation planning attributes for each IBRA region. Conservation planning requires details of the following attributes for each region and for sub-regions therein:

1. key conservation values
2. reservation status
3. deficiencies within the existing system of protected areas
4. types of threats; and
5. alternative conservation management measures.

Source: <http://www.ea.gov.au/parks/nrs/ibraimcr.index.html>

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The underlying premise for such an approach is that physical environmental processes drive ecological processes, which in turn are responsible for the observed patterns of biological productivity and associated patterns of biodiversity. Specialist ecological knowledge is then combined with appropriate biophysical data sets to describe these patterns. The resulting environmental units can be used
for a variety of assessment and planning purposes (Box 8.5).

Box 8.5: Gap Analysis Program, USA

The mission of the Gap Analysis Program (GAP) is to provide regional assessments of the conservation status of native vertebrate species and natural land cover types and to facilitate the application of this information to land management activities. This is accomplished through the following five objectives:

- map the land cover of the US
- map predicted distributions of vertebrate species for the US
- document the representation of vertebrate species and land cover types in areas managed for the long-term maintenance of biodiversity
- provide this information to the public and those entities charged with land use research, policy, planning and management
- build institutional cooperation in the application of this information to state and regional management activities.

It is a cooperative effort among regional, state and federal agencies, and private groups. The purpose of the GAP is to provide broad geographic information on the status of ordinary species (those not threatened with extinction or naturally rare) and their habitats in order to provide land managers, planners, scientists and policy makers with the information they need to make better-informed decisions (Scott and Jennings 1997).

Maps and datasets can be downloaded from the various custodians accessible through the main web site at <http://www.gap.uidaho.edu/default.htm>

8.5.5 Environmental assessment and decision support

The answers to the following questions, i.e.:

- how are environments being managed?
- is something [species, ecosystem, some environmental resource] changing, by how much, is it important, what can be done about it?
- what will happen if …?

are much more complex. Various attempts have been made to develop ecosystem simulation models, expert systems and decision support systems to address these and related issues. Some of these have been outlined in Chapter 2. It is perhaps fair to say that the complexity both of biodiversity itself and in its environmental

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interrelations has confounded attempts to come up with widely applicable systems. Some very successful systems have been developed for certain areas or ecosystems, but these have proved to be of limited applicability outside the domains in which they were developed.

8.6 DISPLAY AND COMMUNICATION

Many decision-makers, such as civil servants, company directors, local government officials and individual resource users, are too busy or lack the technical background to process large amounts of data or apply themselves to difficult interpretation tasks. They need brief summaries of complex issues, presented in such a way that they can be absorbed quickly without the need for special tools or expertise. **Timeliness** is also a critical factor in determining whether information will be effective at supporting decisions. The most salient aspects of a decision may not be taken into account if key information is not available at the right time (World Conservation Monitoring Centre 1998a).

By emphasizing presentation issues such as clarity, timing and method of delivery, information can be made **useful and usable** by its intended audience. The aim is to take account of the constraints under which decision-makers work, and tailor the information accordingly. The results are often referred to as **information products** rather than sources, reinforcing the idea that they are produced with a specific purpose and user in mind (products which are delivered on a regular basis, perhaps via established procedures and mechanisms, are known as **information services**).

Issues in communicating and disseminating results include:

- who is the audience (policy makers, resource managers, other scientists, civil society)?
- what are their interests and capacities to absorb information, i.e. what will they best respond to?
- what is the most appropriate scale and resolution, both to accurately represent the underlying data and to have maximum relevance to the issue under consideration?
- what is the most appropriate display format(s) – reports, charts, maps, on-line scenario analysis?
- what are the most appropriate dissemination technologies – paper, CD-ROM, Internet?

In their original form, scientific research results are notoriously inaccessible to many, due to their level of complexity, sheer volume and focus on scientific rather than policy issues. This is understandable when the results may not have been intended for use in policy-making, for resource management or by the general public. Nevertheless, scientific information could be of much greater value if it is presented in more appropriate ways.

Techniques for translating scientific understanding into 'policy-relevant' information for decision-makers are currently very poorly developed. This is partly due to the traditional 'stand off' between the scientific and policy-making

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communities, fuelled by mutual suspicion of each other's goals and methods, which leads to sentiments such as 'the government never use my data' (scientist) or 'the information was too complicated' (government).

8.7 FUTURE DEVELOPMENTS

Technology is increasingly fading as a constraint on developing our understanding of biodiversity issues(see also Chapter 12). The technologies, both information technology and the analysis, modelling and dissemination tools already available are well beyond the grasp of many scientists, let alone senior decision-makers and the wider public. There are loads of data and many knowledgeable people, both scientists and others. The challenges are in mobilizing what we already know and making it more widely accessible and in identifying and filling gaps in our knowledge. This requires a focus on more interdisciplinary work, the building of collaborative data and information exchange networks, and on improved communications.

The major current and future challenges are largely therefore organizational and people, followed by data documentation, data comprehensiveness and quality.

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8.9 TOOLS AND TECHNOLOGIES

The following list is indicative only. No independent assessment has been made nor is any endorsement expressed. Persons considering using any of these tools should make their own inquiries and assessments.

Name	Type	WWW URL
	Ecosystem process modelling	http://www.nmw.ac.uk/ite/edin/ecos.html
	A one-dimensional upper ocean ecosystem model developed for the central and eastern Pacific Ocean	HTTP://ATHENA.UMEOCE.MAINE.EDU/1DECO-NEW/1DECO.HTM
Alice	Data management	http://dspace.dial.pipex.com/alice/
ANUCLIM	Model climate variables, bioclimatic parameters, and indices relating to crop growth	http://cres.anu.edu.au/software/anuclimtxt.html
BCD	Biological and Conservation Data System	http://www.consci.tnc.org/src/bcdover.html
BG-BASE	Collections management	http://www.rbge.org.uk//BG-BASE/welcome.htm
BG-RECORDER	Plant records management for botanic gardens	http://www.rbgkew.org.uk/BGCI/database.htm
BIOCLIM	Model bioclimatic distributions	SEE ANUCLIM EXAMPLE: http://www.environment.gov.au/search/mapper.html
BioLink	Data and collections management and analysis	http://www.ento.csiro.au/biolink/biolink.html
Biota	Data and collections management	http://viceroy.eeb.uconn.edu/biota
BioTrack	Data management (uses *Biota*)	http://www.bio.mq.edu.au/kcbb/biotrack/default.html
BRAHMS	Botanical Research And Herbarium Management System	http://www.camel.co.uk/brahms/

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Name	Type	WWW URL
Carto Fauna-Flora	Mapping software to represent animals and/or plant distributions	http://panoramix.umh.ac.be/zoologie/cff/cff_en.html
CASSIA	Collections and Specimen System for Information and Analysis	http://www.nybg.org/bsci/cass/spec.html
CENTURY	A general model of plant-soil nutrient cycling	http://nrel.colostate.edu/PROGRAMS/MODELING/CENTURY/C_main.htm
CLIMEX	Predicting the potential distribution and relative abundance of species in relation to climate	http://www.ento.csiro.au/research/pestmgmt/climex/climex.htm
Condor	Planning tool that integrates biodiversity, social, and economic variables	http://www.conservation.org/SCIENCE/CPTC/INFOTOOL/Condor1.htm
DELTA	DEscription Language for Taxonomy	http://www.keil.ukans.edu/delta/
DYMEX	Population modelling	http://www.ento.csiro.au/research/pestmgmt/dymex/dymexfr.htm
FEDMOD	Forest Ecosystem Dynamics Modeling Environment	http://www.ncgia.ucsb.edu/conf/SANTA_FE_CD-ROM/sf_papers/knox_robert/paper.html
FORMIX3	Rain Forest Simulation Model	HTTP://WWW.USF.UNI-KASSEL.DE/MODELLE/FORMIX.HTM
GARP	Designed for predicting the potential distribution of biological entities from raster based environmental and biological data	http://biodi.sdsc.edu/Doc/GARP/Manual/manual.html
Habitat Suitability Index	Uses mathematical models to compute an HSI value for selected species from field measurements of habitat variables	http://www.mesc.nbs.gov/hsi/hsi.html
Linnaeus II	Biodiversity documentation and species identification	http://www.eti.uva.nl/Products/intro_linn.html
MEKA	Identification of biological specimens	http://www.mip.berkeley.edu/meka/meka.html

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Name	Type	WWW URL
Orde	Management of data on the ecology and distribution of insects	http://www.cs.uu.nl/people/jeroen/orde/hl.html
PANDORA	Biodiversity research projects	http://www.rbge.org.uk/research/pandora.home
Platypus	Management of taxonomic, geographic, ecological and bibliographic information	http://www.ento.csiro.au/platypus/platypus.html
PRISMA	Publish databases, generate reports and training materials, and provide information about ecosystems	http://www.conservation.org/SCIENCE/CPTC/INFOTOOL/Prisma1.htm
SimCoast	A fuzzy logic rule-based expert system for analysis of information collected on coastal transects	http://www.ccms.ac.uk/simcoast.htm
Species Analyst	A software extension for ESRI's ArcView GIS software that provide an interface to species distribution prediction models	http://chipotle.nhm.ukans.edu/documentation/applications/SpeciesAnalyst/
SPUR2	A general grassland ecosystem simulation model	HTTP://WWW.GPSR.COLOSTATE.EDU/GPSR/PRODUCTS/SPUR2.HTM
SysTax	Systematic botany and the administration of botanical gardens, herbaria and other collections	http://www.biologie.uni-ulm.de/systax/systax-e.html
TEM	Terrestrial Ecosystem Model	http://baetis.mbl.edu/~dkick/temhp.html
TREEDYN 3	Forest Simulation Model	HTTP://WWW.USF.UNI-KASSEL.DE/DFRAME.PHP3?REFERENCE=/MODELLE/MOD_LEFT.HTM
WORLDMAP	Analysis and mapping	http://www.nhm.ac.uk/science/projects/worldmap/