Measuring Biodiversity: Complex Problems and a Simple Solution

Editor's Introduction | Quantifying biodiversity is a philosophical issue because biodiversity can be seen as encompassing the entire and irreducible complexity of life. Paul Williams of The Natural History Museum, London, evaluates a number of theoretical approaches to measuring biodiversity and introduces Worldmap, unique computer software developed at the museum, which offers an alternative solution to this important problem.

Conservationists have long tried to solve the problem of how to quantify biodiversity. However this is not an easy task: biodiversity can be seen as the irreducible complexity of all life and, as such, no single objective measure is possible, only measures relative to some particular purpose.

For conservationists, a measure of biodiversity should quantify a *value* that is shared broadly among the people for whom the issues at hand are important. One such value is to ensure continued possibilities for adaptation and for use by people in a changing and uncertain world. But what does this mean? What are some practical indicators of such value?

Biologists have argued that this value for potential future use may be associated with richness in the different characters expressed by organisms. For example, a dandelion and a daisy represent fewer characters in total--and so less diversity value--than a dandelion and a pine tree. Thus characters could provide a 'currency' of biodiversity value that needs to be maximized within the conservationists' 'bank'.

The problem with this approach is that the number of characters cannot be counted directly. Biologists have responded by proposing phylogenetic (based on evolutionary development) or taxonomic measures of diversity that estimate, as directly as possible, the relative character richness and biodiversity value of different biotas (biological regions or habitats) based on patterns of genealogical relationships. Of course in practice detailed and reliable phylogenetic information is often not available.

Arguments for measuring biodiversity value as character richness do at least provide a reasoned starting point for developing one possible answer to the question of what is valued in diversity. But accepting the use of genealogical pattern as a predictor of value also provides a possible key to the practical problem of how to measure biodiversity: there are other, even more remote predictors or 'surrogates', some of which have distinct advantages.

When dealing with large numbers of species, species richness can be a reasonable surrogate for character richness, even though it is less direct. This can work because, with a larger total number of species, at least some representatives of the more divergent, higher groups (which are rich in different characters) will usually occur together.

This method is still not a perfect solution, however, because there are probably too many species even within a suburban garden for complete enumeration, let alone for surveys extending across large regions such as the entire Amazon basin.

Hence, the use of surrogates must address two questions: for example, how good is the taxonomic diversity of bird faunas at predicting character richness of bird faunas, and how good is it at predicting (as an 'indicator' group) the character richness of entire biotas? When our interest is in biodiversity in this broad sense, both relationships need to be considered.

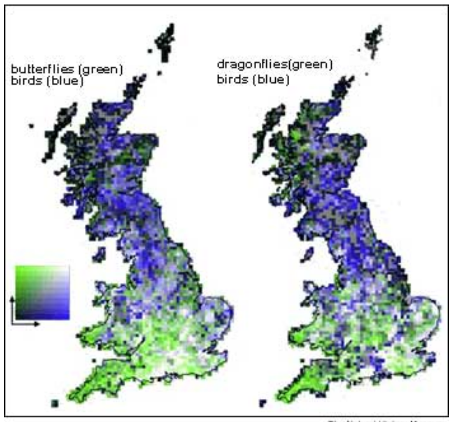
The use of higher taxon richness (using, for example, genera or families) as a surrogate for character richness helps to broaden the taxonomic coverage within biotas and so reduce the enormous extrapolation required when using small indicator groups (i.e., mapping 1,000 families represents a larger slice of biodiversity than mapping 1,000 species). The relationship is not dependent on the 'naturalness' or comparability of higher taxa, providing regional biases are not strong. The choice of taxonomic rank must be made with care, but the approach shows promise of substantially reducing survey costs. Early results show that it may be effective for mapping large areas of biodiversity.

Other surrogates--including classifications of vegetation, land and climate--are still more remote from the level of characters. Yet this level of survey may be very much more practical because it requires less intensive sampling. Certain kinds of information may even be obtained in bulk relatively cheaply by using remote sensing technologies. Furthermore, these larger-scale surrogates are much more likely to include entire functional systems, which are more likely to promote viability.

We need to be very clear as to the purpose of biodiversity measures. In conservation these are likely to differ from such earlier measures as ecological diversity, which were formulated initially with the narrower aim of representing differences in abundance among species and used later for exploring distribution of resources within communities. If instead the value of biodiversity to conservationists is associated with its usefulness to people, then at the outset this ought to be separated carefully from issues of rarity, viability and threat.

Of course conservation can be seen as being fundamentally about viability and threat, but these concepts are distinct from diversity. Measures of viability and threat may perhaps be deployed for maximum effect and accountability at a later stage, in arguments concerning which representative areas or parts of biodiversity should be made the priority for conservation efforts.

The Natural History Museum is engaged in an important international effort to devise ways of assessing priorities for biodiversity conservation, using specialised software called Worldmap.



The Natural History Museum

Worldmap software showing overlay plots comparing the distribution of birds, and two insect groups, in Great Britain.

Worldmap began in 1988. At that time computer mapping was available, but was expensive and much less accessible than it is now. A simple join-the-dots program for an unusual equal-area map projection was required and, as this task was not too difficult, it was simple enough to write a short program from scratch.

In 1990, interest was growing in biodiversity and conservation. At the museum, we asked whether maps could be plotted to show measures that combined species richness with the degree of genetic difference among species. Worldmap was envisaged as an easy platform for developing these biodiversity measures. It was a short step from there to using it for comparing methods that identify important areas for conservation.

Twelve years and 30,000 lines of computer C code later, Worldmap has become a simplified and specialised Windows-based geographic information system (GIS). It does not try to replicate the flexibility and complexity in database and mapping functions of the many commercial GISs.

Instead, Worldmap is used to develop new analytical tools, applying them at high speed to large data sets, so that it can be used to explore issues relevant to biogeography and conservation. These include such questions as: Which combination of areas could represent the most biodiversity for conservation? Answering this is not as straightforward as it may seem.

Conservation is a topic that can cause many conflicts. What one person may view as being important to protect may not concur with another's opinion. Quantitative methods are designed to make this process as explicit and accountable as possible, so that conservationists can demonstrate that they are working effectively on behalf of the people giving them their mandate. A tool was needed that could help decision-makers to support their decisions with the best available biodiversity information. We attempted to implement these methods in a user-friendly way, with the intention that people should be able to pick up the basics and learn about the ideas behind the methods easily and without formal training. Worldmap has helped The Nature Conservancy in the United States to distribute methods and data to people working with bird conservation in Latin America. Conservation International and WWF have also used Worldmap in regional priority-setting workshops to explore important areas for the conservation of biodiversity in Africa.

Identifying important areas for the conservation of biodiversity is complicated by the need to take account of many constraints. Frequently these constraints include consideration of the existing network of conservation areas and budgetary limitations (knowledge of which depends on information about the costs of acquiring areas, the cost of management, and the cost of opportunities forgone, such as certain kinds of forestry and agriculture). Crucially, there is also need for information on viability and threat for populations within realistic management areas, which is essential for ensuring the persistence of species.

Eventually, assessing for biodiversity conservation may amount to no more than putting information from good ecological studies on a large number of species within a larger framework, in order to help fill 'gaps' in the conservation system. At present, however, the aim is to make the most of relatively limited information. Fortunately it is possible to begin to identify important areas when presented with nothing more than basic atlas data for species.

Because of the difficulties encountered in acquiring data for all biodiversity, conservationists are also interested in the similarities in distribution between groups of organisms, hoping that some well-known groups might be used as indicators. Collaborative work on African fauna has looked at whether choosing conservation areas for the few popular flagship species (such as gorillas, chimpanzees and elephants, which are used to promote fund-raising initiatives) is really a good way to represent broader biodiversity. Results from Worldmap show that using flagship species from a broad variety of habitats is not enough: the chosen species must also have non-overlapping distributions to ensure that more of the variety of habitats is represented. Consequently, there may be a need for an explicit policy of balancing the need for flagship conservation against broader biodiversity conservation, which has implications for the distribution of scarce resources.

Books:

Title: Biodiversity : A Biology of Numbers and Difference
Format: Paperback
Author: Gaston, Kevin J.
Date: 01-JUN-96
ISBN: 0865428042