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Biodiversity measurement determines stability of ecosystems

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ABSTRACT

Biodiversity is the sum total of all biotic variation from the level of genes to ecosystems and is often used as a measure of the health of biological systems. Phylogenetic and temporal analyses are shedding light on the ecological and evolutionary processes that have shaped current biodiversity. Humans are now destroying this diversity at an alarming rate and this loss affects ecosystem functioning. Species richness is often used as a criterion when assessing the relative conservation values of habitats or landscapes. An area with many endemic or rare species is generally considered to have higher conservation value than another area where species richness is similar, but all the species are common and widespread. Stability of an ecosystem depends upon the biodiversity parameters.

Keywords-biodiversity; measurement; stability; ecosystem

1. INTRODUCTION

Any attempt to measure biodiversity quickly runs into the problem that it is a fundamentally multidimensional concept and it cannot be reduced sensibly to a single number [1-2]. No single measure will always be appropriate (indeed, for some conservation questions, no single measure can probably ever be appropriate). The choice of a good measure is complicated by the frequent need to use surrogates for the aspect in which we are most interested [3-4]. Finding new large vertebrates nowadays is indeed newsworthy, but a new species of large mammal is still discovered roughly every three years [5] and a new large vertebrate from the open ocean every five years [6]. Based on rates of discovery and geographical scaling-up, it seems that the roughly 1.75 million described species of organism may be only around 10% of the total [7]. Cycliophora and Loricifera are animal phyla (the level just below kingdom in the taxonomic hierarchy) that are new to science in the past 20 years [8]. Within the Archaea, the discovery of new phylum-level groups proceeds at the rate of more than one a month [9]. Subsurface lithoautotrophic microbial ecosystems may have persisted for millions of years without any carbon from the surface [10]. Controversy surrounds another proposed discovery: whether or not the 100-nm-diameter nanobacteria found in, among other places, kidney stones are living organisms [11]. At an even smaller scale, genomes provide fossils that indicate great past retroviral diversity [12].

Genomes have also been found to provide habitats for many kinds of genetic entity — transposable elements — that can move around and replicate themselves. Such elements can provide important genetic variation to their hosts, can make up more than half of the host's genome [13], and have life histories of their own [14]. There are two other ways in which the biosphere can perhaps be said to be growing. The first is that the rate at which taxonomists split one previously recognized species into two or more exceeds the rate at which they lump different species together, especially in taxa that are of particular concern to conservationists, for example, platyrrhine primates [15]. Part of the reason is the growing popularity of one way of delimiting species — the phylogenetic species concept (PSC) [16] under which taxa are separate species if they can be diagnosed as distinct, whether on the basis of phenotype or genotype. If the PSC becomes widely applied, which is a controversial issue [17] then the numbers of 'species' in many groups are sure to increase greatly [18]. The ongoing explosion of phylogenetic studies not only provides an ever-clearer snapshot of biodiversity today, but also allows us to make inferences about how the diversity has come about [19-21]. They detail the pattern of nested relationships among species, and increasingly provide at least a rough timescale even without reliance on a molecular clock [22].

The palaeontological record indicates a Cambrian explosion of phyla around 540 million years (Myr) ago, but sequences suggest a more gradual series of splits around twice as old [23]. Likewise, many orders of mammals and birds are now thought to have originated long before the end-Cretaceous extinction [24-25]. If the new timescale can be trusted [26], these findings present a puzzle and a warning. Animals were too small or too rare, with the sudden appearance in the rocks corresponding to an increase in size and rise to ecological dominance [27]. Darwin [28] had noted that species in species-rich genera had more subspecific varieties, and subtaxa within taxa are often distributed very unevenly [29]. It is clear that workers on different groups currently place taxonomic boundaries in very different places [30]. Time and again, species are distributed too unevenly for simple null models to be tested in which all species have the same chances of diversifying [31-32].

2. MEASURING BIODIVERSITY

Biodiversity is a contraction of 'biological diversity' and is used to describe the variety of life. It refers to the number and variety of organisms within a particular area and has three components: species diversity; ecosystem (or habitat) diversity; and genetic diversity. Species diversity relates to the number of the different species and the number of individuals of each species within any one community. A number of objective measures have been created in order to measure species diversity. Species richness is the number of different species present in an area. The more species present in a sample the 'richer' the area.

2.1 Simpson's diversity index

Species richness as a measure on its own takes no account of the number of individuals of each species present. It gives equal weight to those species with very few individuals and those with many individuals. Thus, one daisy has as much influence on the richness of the area as 1000 buttercups. A better measure of diversity should take into account the abundance of each species. To illustrate this, compare the data for wildflowers sampled in two different fields. The species richness is the same and the total abundance is the same, but field B is dominated by just one species – the buttercup. A community dominated by one or two species is considered to be less diverse than one in which several different species have a similar abundance. Simpson's index (**D**) is a measure of diversity, which takes into account both species richness, and an evenness of abundance among the species present. In essence it measures the probability that two individuals randomly selected from an area will belong to the same species. The formula for calculating D is presented as: $D = \frac{\sum n_i(n_i - 1)}{N(N-1)}$ where n_i = the total number of organisms of each individual species, N = the total number of organisms of all species. The value of **D** ranges from 0 to 1. With this index, 0 represents infinite diversity and, 1, no diversity. That is, the bigger the value the lower the diversity. This does not seem intuitive or logical, so some texts use derivations of the index, such as the inverse (1/D) or the difference from 1 (1-D). The equation used here is the original equation as derived by Edward H. Simpson in 1949. Note that this equation will always be shown in a question where you are asked to calculate Simpson's index. To calculate Simpson's index for a particular area, the area must be sampled. The number of individuals of each species must be noted. For example, the diversity of the ground flora in woodland might be determined by sampling with random quadrats. The number of plant species in each quadrat, as well as the number of individuals of each species should be noted. There is no necessity to be able to identify all the species provided that they can be distinguished from each other. Further, percentage cover can be used to determine plant abundance but there must be consistency, either all by 'number of individuals' or all by 'percentage cover'.

2.2 ***Low versus high species diversity***

Low species diversity suggests relatively few successful species in the habitat; the environment is quite stressful with relatively few ecological niches and only a few organisms are really well adapted to that environment; food webs which are relatively simple; change in the environment would probably have quite serious effects. High species diversity suggests a greater number of successful species and a more stable ecosystem; more ecological niches are available and the environment is less likely to be hostile; complex food webs; environmental change is less likely to be damaging to the ecosystem as a whole. Species biodiversity may be used to indicate the 'biological health' of a particular habitat. However, care should be used in interpreting biodiversity measures. Some habitats are stressful and so few organisms are adapted for life there, but, those that do, may well be unique or, indeed, rare. Such habitats are important even if there is little biodiversity. Nevertheless, if a habitat suddenly begins to lose its animal and plant types, ecologists become worried and search for causes (e.g. a pollution incident). Alternatively, an increase in the biodiversity of an area may mean that corrective measures have been effective.

2.3 Ecosystem (habitat) diversity

This is the diversity of habitats or ecosystems within an area. A region possessing a wide variety of habitats is preferable, and will include a much greater diversity of species, than one in which there are few different habitats. More specifically a countryside which has ponds, river, woodland, hedgerows, wet meadowland and set-aside grassland will be more species rich and more diverse than countryside with ploughed fields, land drained and without wet areas and devoid of woods and hedgerows.

2.4 Genetic diversity

This is the genetic variability of a species. Genetic diversity can be measured directly by genetic fingerprinting or indirectly by observing differences in the physical features of the organisms within the population (e.g. the different colour and banding patterns of the snail *Cepea nemoralis*). Genetic fingerprinting of individuals within cheetah populations has indicated very little genetic variability. Lack of genetic diversity would be seen as problematic. It would indicate that the species may not have sufficient adaptability and may not be able to survive an environmental hazard. The Irish potato blight of 1846, which killed a million people and forced another million to emigrate, was the result of planting only two potato varieties, both of which were vulnerable to the potato blight fungus, *Phytophthora infestans.*

3. STABILITY & FUNCTION OF ECOSYSTEM

Principal environmental factors such as climate, soil type and disturbance [33-34] strongly influence ecosystem functioning, but likewise organisms can affect their environment [35]. Some of the first ideas on how biodiversity could affect the way ecosystems function are attributable to Darwin and Wallace [28, 36], who stated that a diverse mixture of plants should be more productive than a monoculture; they also suggested the underlying biological mechanism: because coexisting species differ ecologically, loss of a species could result in vacant niche-space and potential impacts on ecosystem processes. Defining ecological niches is not straightforward, but Darwin and Wallace's hypothesis, if correct, provides a general biological principle which predicts that intact, diverse communities are generally more stable and function better than versions that have lost species. Compared with systems that have lost species, diverse plant communities often have a greater variety of positive and complementary interactions and so outperform any single species [37-38], and have more chance of having the right species in the right place at the right time. This last 'sampling effect' mechanism has prompted much debate on the design, analysis and interpretation of experiments that aim to manipulate biodiversity [39]. Although the sampling effect is biological in part, it requires both differences between species and an ecological mechanism making some species more abundant than others, the probabilistic component (more diverse communities have a greater chance of containing a species with particular properties) has made it controversial. Nevertheless, loss of species with key traits, as in the sampling effect, is not restricted to ecological experiments: logging, fishing, trapping and other harvesting of natural resources frequently remove particular organisms, often including dominant species.

Although 95% of experimental studies support a positive relationship between diversity and ecosystem functioning, many have found that only 20–50% of species are needed to maintain most biogeochemical ecosystem processes [40]. Biodiversity can also impact ecological processes such as the incidence of herbivory and disease, and the resistance of communities to invasion. Once again, although exceptions exist, in experiments which manipulate diversity directly, communities with more species are often more resistant to invasion [41-42], probably for the same reason that they are more productive. Diversity of one group of organisms can also promote diversity of associated groups, for example between mycorrhizas and plants [43] or plants and insects [44]. The study of the relationship between biodiversity and ecosystem processes has made rapid progress in the past decade, and is proving an effective catalyst for linking the ecology of individuals, communities and ecosystems. Some general, although not universal, patterns are emerging as theory and experiment progress together. Niche differentiation could cause changing diversity to have consequences for ecosystem processes, but the magnitude of these effects could depend crucially on the exact mechanism of coexistence. Finally, how do we integrate these new within-habitat relationships between diversity and ecosystem processes with large-scale patterns in biodiversity and environmental parameters, are important to investigate.

4. CONCLUSION

Biodiversity measurement is helpful in determining stability of ecosystems. Biodiversity is a measure that combines richness and evenness across species. It is often measured because high biodiversity is perceived a synonymous with ecosystem health. Diverse communities are believed to have increased stability, increased productivity, and resistance to invasion and other disturbances. Although biodiversity can never be fully captured by a single number, study of particular facets has led to rapid, exciting and sometimes alarming discoveries. Diverse habitats with a variety of plants can have benefits such as providing forage for a variety of insect and vertebrate species. Stability resulting from plants in the communities that are able to survive drought, insect plagues, and/or disease outbreaks so that the site will have some soil protection/forage/etc. in those years. Plants containing a variety of genetic material are useful in long-term survival and stability of the community. The community benefits from a mixture of plants includes as soils improve with nitrogen fixers, deep rooted plants bring nutrients up from soil layers below other plants roots. Some species work together so that both can survive (called commensalism) and therefore, diverse communities can be more stable. Healthy diverse plant communities generally have all niches filled and are theoretically less likely to be invaded by noxious or opportunistic introduced species. Biodiversity estimation and measurement provide information for understanding the stability of ecosystems. There is need for further research to visualize the important aspects of ecosystems and their stability with respect to biodiversity.

5. REFERENCES

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