What is Biodiversity?

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Biodiversity, shorthand for biological diversity, is an ambiguous term that has a wide variety of different biological implications. In 1992 it was formally defined in the Convention on Biological Diversity, a treaty agreed upon by over 150 countries representing key agreements in conservation biology *(Laikre L et al, 2008)*. In this treaty biodiversity was declared as *"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" (www.cbd.int, 10/11/2018)*. In essence, biodiversity can be thought of as being used interchangeably with the phrase 'variety of life', thus referring to a wide range of different forms of natural variation *(Gaston KJ, 2010)*. Despite this fairly neutral definition, the phrase 'biodiversity' has become heavily laden with connotations in popular science, with the inference being that it is a good thing and its loss is bad. This highlights the idea that more of the concept can be gauged than what is solely suggested within its formal definition, especially with regard to human morals. Generally speaking however, the form that biodiversity takes in practice can be compartmentalised and are studied at three differing levels of biological organisation; namely genetic, organismal and ecological diversity *(Gaston KJ & Spicer JI, 2004)*.

Genetic diversity refers to the genetic makeup of organisms at all levels (nucleotides, genes and chromosomes) and the variation that exists in these components between individuals as well as between populations *(Gaston KJ & Spicer JI, 2004)*. It is an incredibly important element when assessing biodiversity as the genetic components of an organism provide the raw material on which natural selection can act upon. When studying all levels of biodiversity, genetic diversity is often considered to be the easiest to describe and it is more readily defined due to the discrete nature of genetic elements. It is commonly measured within species in terms of allelic diversity (number of alleles per locus), nucleotide differences or gene diversity (heterozygosity across loci) *(Gaston KJ, 2010)*. Genetic diversity often seems to fluctuate in a predictable way with other variables. For example, large populations, stable populations and populations at the centre of a species' geographic range all generally have greater genetic diversity than their alternatives. These differences in diversity can lead to a variety of population-level changes resulting in effects on the organismal and ecological diversity in the region in which they are found *(Hughes JB et al, 2008)*.

Organismal diversity encompasses the variation at all taxonomic hierarchies, from species upwards to phyla and kingdoms. It includes some of the most recognisable measures of biodiversity, such as the raw number of species present in an area, known as species richness *(Gaston KJ, 2010)*. One fundamental way in which organismal diversity is measured is the use of diversity indices on a species level. These are mathematical equations that combine both species richness and species evenness (a parameter which represents the relative abundance of species at a site) to calculate a numerical value that indicates the species diversity, this includes

Shannon's, Simpson's and McIntosh's Indices *(DeJong TM, 1975)*. This is a popular way of quantifying biodiversity as a whole because species diversity may act as a surrogate for other measures of diversity, as a greater number of species implies greater diversity of genes (and therefore genetic diversity) and a greater number of ecological niches, habitats and interactions (and therefore ecological diversity) *(Gaston KJ & Spicer JI, 2004)*. However, it is contentious as to whether calculated species diversity is entirely representative of organismal biodiversity, due to the ambiguous nature of whether all species contribute equally to biodiversity. The measure of this diversity should therefore aim to incorporate information about how the species present in a site are related to each other. One way that attempts to overcome this are taxic measures, which is a method that asks whether the number of higher taxa provides a more appropriate measure for biodiversity than just the raw number of species *(Harper JL & Hawksworth DL, 1994)*. However this still brings with it problems, such as the issue that taxonomic ranks are ultimately arbitrary measures imposed by humans. As well as this, community biodiversity may comprise of differences between organisms that are comparable in magnitude but expressed at different taxonomic ranks. Despite this, organismal diversity can still be seen as a component of biodiversity that, at a simple level, is greater when there is a greater number of unrelated organisms.

Ecological diversity refers to the differences in larger scale factors relating to ecosystems, from populations to components such as niches and habitats. Although it may seem obvious at first that these elements vary and break up different ecological phenomena, it is practically not that easy to formally distinguish the difference between one type and another. For example, it is hard to state exactly when one habitat ends and another begins, or exactly how many niches are present in an area, because they are essentially abstract concepts *(Gaston KJ, 2010)*. Therefore, there has recently been a call to quantify such concepts, leading to a growing sense of standardisation of the schemes used. A common unit of ecological diversity lies in the idea of 'ecoregions', which can be thought of as areas of land containing certain assemblages of communities and species, with boundaries that approximate the prior extent of natural communities before a change in land-use. In a paper by Olson et al, the terrestrial world was divided into fourteen biomes and eight biogeographic realms, within these were 867 ecoregions *(Olson DM et al, 2001)*. This has produced a fairly thorough insight as to how ecological diversity manifests itself across the globe; with hotspots appearing that have many more ecoregions in a distinct area than other latitudes with the same total area, thus indicating a higher biodiversity at an ecological scale.

These three components of biodiversity, although perhaps being a slightly simplified way of viewing the concept, provide a way of understanding how natural diversity and variation can be observed at different levels of biological complexity.

The Importance of Biodiversity

It is often overlooked as to why, as humans, the vast majority of us seem to view biodiversity as a 'good' thing and something worth conserving. From the smallest scales whereby households wish to attract species to their garden to global-scale conventions and treaties, it is evident that the urge to maintain the variety of life is present across the world in different cultures and populations. The reason for the existence of this desire is in no way agreed upon, and invites debate regarding natural human duty and even religion. Despite this subjective complexity, the importance of biodiversity can still be deliberated on a quantifiable and more basic biological level. Biodiversity can be seen to be beneficial to the human species by having two different broad 'values'; these are use values (comprised of direct and indirect use values) and non-use values (comprised of option, bequest, existence and intrinsic values) *(Gaston KJ & Spicer JI, 2004)*.

Use Values

Use values refer to the services provided by ecosystems that are made possible only through the maintenance of biodiversity. As stated, they comprise of both direct and indirect use values. Direct use values of biodiversity consist of biological components of ecological communities that can be actively used as commodities for human use, including medicinal products, food and building materials *(Gaston KJ & Spicer JI, 2004)*. The direct use value with perhaps the largest effect on the human population is biodiversity's association with the production of food. Currently, out of approximately 300,000 angiosperms, 12,500 are considered to be appropriate for human consumption *(Rapoport EH & Drausal BS, 2001)*. Only 200 plant species have actually been domesticated for food and 75% of human food supply is obtained from just 12 plants *(United Nations Development Programme et al, 2000)*. This shows the huge potential that the world's biodiversity contains for feeding the growing population and stabilising the global food security crisis *(Sunderland TCH, 2011)*. As well as the potential for there being wild species that are yet to be domesticated, there is also the possibility that wild relatives of agricultural species could have greater genetic diversity which could be incorporated in crops to improve a variety of traits *(Thrupp LA, 2000)*. Another major direct use value is that of medicinal products. 60% of the world's population relies almost entirely on plant-based medicine for primary healthcare and of the new drugs approved between 1982 and 1994, 39% were directly taken or derived from natural products *(Harvey A, 2000)*. Therefore, biodiverse regions of the world have the potential to contain many plant, and even animal, products that could be of use in medical research and treatment. Although the medicinal and food benefits that biodiversity brings are the primary direct use values, others exist such as industrial materials, biological controls, recreational harvesting and ecotourism *(Gaston KJ & Spicer JI, 2004)*.

Indirect use values refer to ecosystem services that contribute advantageously to the human population, but not through the production of commodities that can be traded, for example nutrient cycling services and climate regulation *(Gaston KJ & Spicer JI, 2004)*. In a large-scale experiment by a committee of ecologists, a 3.15 acre closed-environment facility was constructed and named Biosphere 2. Experiments were undertaken which gave insight into the importance of biodiversity regarding indirect use values. It proved impossible for the closed system to support just eight humans' livelihoods with enough food, water and air for 2 years. This was an important finding, making it clear that natural ecosystem services are absolutely essential for the maintenance of human life and cannot be replicated through human technology alone *(Cohen JE & Tilman D, 1996)*. This is particularly prominent given that such services cannot take place without a certain threshold level of biodiversity. This is because when there is greater biodiversity, there is a larger pool of species and thus a higher likelihood that certain species will be present that are involved in prominent ecosystem functions, known as the sampling effect. It is also the case that when there are more species, more niches are being filled and thus resources are being exploited more thoroughly and there is higher productivity, known as species complementarity. Additionally, when there are more species there is a higher frequency of positive interactions between species thus increasing ecosystem functioning *(Gaston KJ & Spicer JI, 2004)*.

Both direct and indirect values indicate how maintaining biodiversity is important for preserving an ever-growing human population, and how particularly biodiverse hotspots may be sustainably exploited to benefit humans.

Non-use Values

Non-use values are associated with resources that are neither directly nor indirectly exploited and can be divided into four different components. The first is 'option value', which refers to the idea that biodiversity should be maintained for its potential that may be of use in the future *(Weisbrod B, 1964).* The second is 'bequest value', which is highly related to biodiversity's option value and refers to passing on the resources to future generations *(Krutilla JV, 1967)*. The third is 'existence value', which is slightly more abstract than the other values and refers to the idea that species have a value to people even if they do not have any direct or indirect use. The final value is 'intrinsic value', referring to the idea that humans have a moral obligation to protect all life *(Ehrlich PR & Wilson AH, 1991)*. The latter two values are fairly contentious as it is ambiguous as to whether they really exist and cannot be quantified in any way as such. These non-use values propose why biodiversity should be maintained without explicitly giving direct and indirect uses of the resources found within areas of biodiversity.

The Relevance of Biodiversity

Biodiversity is of great relevance to humans due to the association between the most biodiverse regions and their stable state. By protecting biodiversity, we are protecting the stability of ecosystems that provide services that we are dependent on for survival, such as the maintenance of climate, production of food and association with the water cycle *(Gaston KJ & Spicer JI, 2004)*.

Despite our dependence on these services, the ever-growing human population is having adversely negative effects on biodiversity. Moreover, regions where population growth is at its highest often correlates with biodiversity hotspots, thus putting the most valuable ecosystems at risk of destruction and fragmentation. The annual rate at which populations have been growing in these regions is greater than the global average (at 1.8% between 1995 and 2000) and despite only covering 12% of the earth's surface it contains 20% of the population. The high population density and growth in these regions poses particular threat due to urbanisation, increased pollution and unsustainable exploitation of resources thus leading to severe habitat and species loss *(Cincotta RP, Wisnewski J & Engelman R, 2000)*.

With increasing threat being posed to biodiversity hotspots coupled with the increasing knowledge of the services and values that comes with biodiverse regions, the relevance of its loss has never been so eminent. Through their direct, indirect and future benefits that regions of biodiversity bring to human populations, it is critical that we make efforts to conserve and protect them.

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