Biodiversity – what does it mean?

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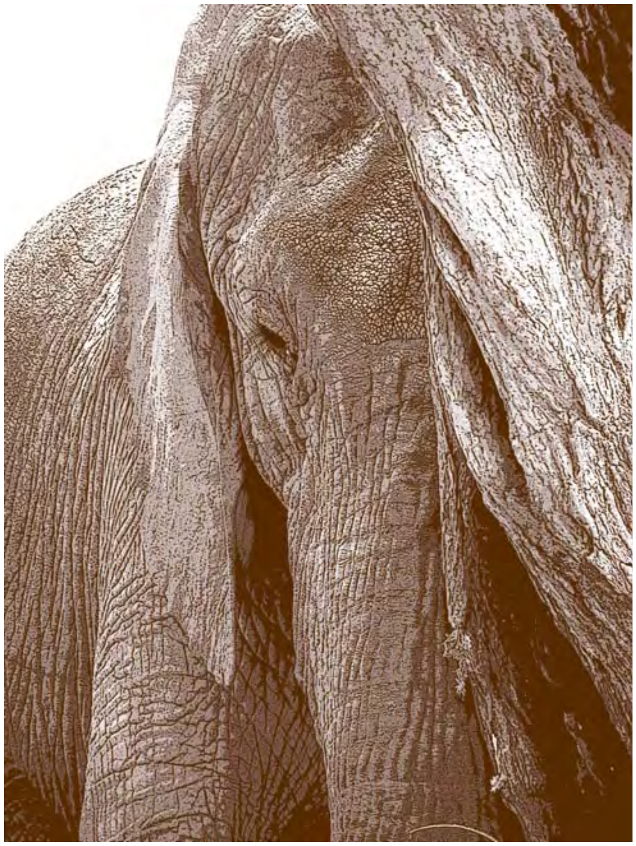

Truth is that which one wishes for in its totality. Have you reached it?
Krishnamurti

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SAVE THE ELEPHANTS

TRANSBOUNDARY ELEPHANT RESEARCH PROGRAMME

Some important definitions and concepts

Table 1. Some important definitions and concepts in relation to their complexity both in terms of temporal and spatial scales

Scale of complexity	Concept	Definition
Low	*Species richness*	Refers to the number of species present
	Species diversity	Takes into consideration the species richness (or number of species) and the evenness with which individuals within the community are distributed. Incorporates both the number of species and their relative abundance.
	Keystone species	Important species that are critical to the community because their activities determine the community structure.
	Umbrella species	A species whose protection and conservation will automatically include the protection of smaller less prominent species because their niche requirements are less demanding on the system or simply not as visible.
	Niche	The limits, for all important environmental features, within which individuals of a species can survive, grow and reproduce.
	Alpha-diversity	Refers to the number of species within a single habitat/community, hence the within-community species richness
	Population	A group of individuals of a single species
	Deme	Interbreeding group in the population also known as a local population.
	Community	Group of populations of plants and animals in a given place. This ecological unit incorporates groups of various sizes and degrees of integration.
	Beta-diversity	Refers to the difference between adjacent biotic communities and can be measured as the difference in species composition between various communities, hence habitat diversity or species turnover along a series of habitats
	Guild	Represents a group of species exploiting a common resource base in a similar fashion. For example a guild of nectar using species (bees, humming birds, moths, butterflies). Competitive interactions amongst members of a guild are usually strong. By grouping species into guilds we are in fact placing them in functional groups within the ecosystem.
	Ecosystem	A holist concept of the plants, the animals habitually associated with them and all the physical and chemical components of the immediate environment or habitat which together from a recognisable self-contained entity.
	Resilience	A measure of the ability of a system to persist in the presence of perturbations arising from weather, physical-chemical factors, other organisms, or human activities. Resilience is measured by the probability of extinction.
	Gamma-diversity	Refers to the total species diversity of a large geographic region (e.g. a landscape or larger).
high	***Biodiversity***	**Biodiversity is taken to be the integration of biological variability across all scales, from genetic, through species and ecosystems to landscapes.**

Why conserve biodiversity?

- Conserving biodiversity has value from an **ethical** perspective which borders on the religious or quasi-religious intrinsic value of life forms and the need to preserve them. According to Ehrenfeld (1978), species and communities should be preserved because:
  ‘they exist and because this existence is itself but the present expression of a continuing historic process of immense antiquity and majesty. Longstanding existence in Nature carries with it the unimpeachable right to continued existence.”
- As all organisms exhibit at the very least the beauty of design, they need to be conserved for **aesthetic** reasons.
- As we derive **direct economic value** from biodiversity by acquiring food, drug derivatives, fuel and the genetic library for potential developments both in the food and drug industry, we need to conserve biodiversity. Biodiversity also has economic value through tourism and therefore is justified in human social-economic development terms. Linking ecological concepts to economic ones are important as economic incentives can alter behaviour.
- Biodiversity also provides many **indirect benefits** to all life forms such as generating and maintaining soils, biogeochemical cycles such as the nitrogen cycle and photosynthesis maintaining the atmospheric and gaseous composition. Put simply, life on earth depends on these systems and cycles.

Approaches to biodiversity

The dilemma with biodiversity conservation is that our level of understanding the principles behind concepts such as alpha-diversity, which lie on the lower end of the scale of complexity (refer to Table 1) and which are often the focus of any biodiversity strategy, are insufficient for us to know the outcome of biodiversity conservation with precision. Hence adherence to a policy that places equal emphasis on every species is ecological unsound and tactically unachievable partly because we still don’t know and may never know all the species in a given system and partly because not all species function in the same way. Generally only a small number of species have a major role in ecosystem processes. Some species are ‘drivers’ of ecosystem function and others are ‘passengers’. Removing drivers will cause a cascade effect while passengers can be lost with little change in the rest of the ecosystem. To establish the functional role of species in an ecosystem generally takes a number of years and different climatic cycles because when a system is stressed or perturbed, a larger number of species perform a buffering role and contribute towards the resilience of the system. We need to be asking what kinds of biodiversity are important to ecosystem functioning? We need to realise that the best way to minimize species loss is to maintain the integrity of ecosystem function. Having this approach will force us to address issues relating to biodiversity conservation at larger spatial and temporal scales. Unless we attempt to understand underlying principles we will stand no chance of predicting patterns.

The goal of biodiversity conservation is to reverse the process of biotic impoverishment **at each** of the levels of organisation. Therefore a decline in biodiversity includes all the changes that reduce or simplify biological heterogeneity (patchiness), from individuals to regions. Maintaining ecological complexity should incorporate far more than just protecting threatened or endangered species. Biodiversity conservation should make allowance for:

- plasticity in the expression of the characteristics of an organism as determined by the interaction between the genotype and its environment (phenotypic plasticity)
- a wide range of genotypic responses to environmental conditions (genetic variability within a population)
- Genetic variability between populations within a species (ecotypic variation)
- The number of species in a community (species richness)
- The number of species and the relative numbers of individuals per species in a community (alpha diversity)

- The relative abundances of functionally different kinds of organisms (functional diversity)
- Diversity in species composition between adjacent communities (gradient or beta diversity)
- Diversity resulting from speciation of ecological equivalents (gamma diversity)
- The number, size and spatial distribution of communities, sometimes referred to as patchiness (community diversity)
- The diversity of the scales of patchiness (landscape diversity)

Too often biodiversity conservation involves the maintenance of taxonomic species and centres on species lists. This trend in biodiversity conservation probably came from the uncritical acceptance of an assumed positive relationship between species richness and 'stability' but evidence now points to the fact that diversity at the community level (patchiness) is important in long-term stability. Ecological and evolutionary processes are as much as a concern in biodiversity conservation strategy as are species diversity and composition. If one considers that 99% of all species that have existed on earth are now extinct, extinction itself is not detrimental but is part of the evolutionary process. Biodiversity conservation should represent a step beyond endangered or threatened species conservation. Biodiversity must be understood dynamically in terms of processes rather than merely the maintenance of current elements of the system. We should focus our attention on those aspects of biodiversity that are critical for maintaining ecosystem resilience and strive to understand how much or how little redundancy there is in the biological composition of the ecosystem. By examining the interaction and historic occurrence of species we can determine whether the removal of one species results in the density compensation amongst the remaining species, which usually indicates redundancy of the removed species. We should strive to set biodiversity policy at landscape level because by maintaining the integrity of ecosystem function on large spatial scales we minimise the chances of losing many species we have not yet described.

Methods.

We here attempt to summarise the various ways in which ecosystems can be managed. We believe that none of these management approaches can be mutually exclusive but some may be more appropriate than others and their applicability will depend on the scale (both spatial and temporal) at which the manager wishes to conserve the ecosystem (Table 2). We then list some practical tips which are broad enough to incorporate a number of the management approaches that have been presented. Successful policy should encourage a patchy landscape while an accelerated extinction rate of species at a broadened scale should be reason for concern.

Table 2. Various methods to approach the management of ecosystems to ultimately increase biodiversity. Adapted from Noss (1983) and Hansen *et al.* (1999)

Scale	Name	Concept	Method	Advantage	Disadvantage
Alpha-diversity	Species prioritisation	Identify species most at risk so that management can be directed at them	• Using existing life history and other data to rank viability. • Aim to achieve a greater range of resources, more specialised species, extended exploitation of the resource base and greater overlap between species in terms of resource use without promoting competition by boosting limited resources, controlling unwanted species and by increasing structural complexity to provide more physical niche space.	• Increased number of species within a habitat. • Desired community structure maintained.	• May be arduous and costly to implement. • Considerable uncertainty about the effects of management actions on particular species (undesirable species could reach pest proportions, and critical species could decline)
	Population Viability Analysis	Analyse population demography to assess risk of extinction	Use complex demographic models to assess species viability under varying management strategies.	Increased population levels of particular species	• Requires specific knowledge about founder population, mortality rates etc. • Implementation plan to protect particular populations would have the same disadvantages as species prioritisation.
Beta-diversity	Maximum Local Habitat diversity	The emphasis is placed on 'edge' development where an edge is defined as a place where plant communities meet or where successional stages within plant communities come together. Edges generally contain animals from adjacent vegetation types, animals that prefer one or the other neighbouring communities and animals that are specialised to live on edge habitats. Consequently edges have a high species turnover	• Maintain a variety of successional stages so that degenerative changes in some portions of the community are balanced by regenerative changes in other portions. • Intersperse different habitat types • Construct roads, trails and other swaths to increase 'edge' effects	• Increased local species richness • Increased population levels of edge-adapted species • Increased human recreational potential	• Decreased population levels or extirpation of interior specialists • Proliferation of 'weedy' opportunistic species • Community destabilisation • Possibly decreased regional diversity

Table 2. (continued)

Scale	Name	Concept	Method	Advantage	Disadvantage
Gamma-diversity	Dynamic Habitat Modelling	Based on the assumption that species abundances are related to habitat suitability. Hence the configuration of suitable habitat for each species is a measure of extinction risk.	Quantify/project change in suitable habitats for each species under varying management scenarios	• Adequate population levels and genetic variation of indigenous species maintained • Critical ecosystem processes perpetuated • Long-term human welfare promoted	• Some loss of local species richness with decline in edge species • More land taken out of 'productive' human uses • Short-term economic losses
	Dynamic Habitat and Population Analysis	Identify the species and places most at risk and focus research and management on these	Use a hierarchical set of filters to identify and manage the species and places most at risk		
	Gap analysis/Critical Ecosystems analysis	Identifies the gaps in ecosystems that contain species and/or processes that are poorly protected so that local management can include new reserves or changes in land use practises	Rank ecosystems based on native species, threats to ecosystem, and other factors. Make use of actual vegetation types (scales can be large by using satellite imagery) and vertebrate and invertebrate species as indicators of, or surrogates for biodiversity.		
	Ecological Process Management	Maintain key ecological processes like disturbance, succession and landscape structures to maintain species adapted to these conditions	Analyse interactions among ecological processes and structures and manage to maintain them.		

Practical tips

1) Set clear goals/objectives. Objectives such as 'optimising biodiversity' are too general.
2) Goals should define:
   - the response variable (entity that will be monitored and managed)
   - the organisation level of interest (species, deme, community, ecosystem)
   - the response variable within each level (threatened species at species level, functional groups at community level or number of different communities at ecosystem level)
   - the target at each organisational level (maximise species richness or secure vulnerable species at species level, minimum population viability at population level, specific ratio of seral stages or guilds within a community or resilience at ecosystem level)
   - temporal and spatial scales over which the target level of the response variables are to be maintained. Objectives for a particular spatial or temporal scale should be set with respect to broader scale constraints and finer-scale mechanisms. Animal and habitat relationships should be measured over a range of spatial and temporal scales where habitat includes not only vegetation type but also primary productivity, geomorphology, hydrology, soils and disturbance history. Differences in scales are often function of differences in life history attributes such as body size, metabolic rate and home range size.
3) Adopt a hierarchical approach to defining your response variable within each organisation level.
   - At species level attempt to prioritise the following types of species:
     flagship/charismatic species because of their tourist attraction and the economic benefits derived from conserving such species
     umbrella species which assist in the conservation of lesser known species
     keystone species which drive ecosystem processors
     indicator species which indicate change in ecological processes
     vulnerable species which usually have life-history traits that make them vulnerable to extinction and which include a short longevity, low reproductive rate, constrained dispersal, specialisation on particular food or habitats and hence a sensitivity to habitat change or a large home-range.
   - At population level determine the uniqueness of the population in terms of their distribution (right up to regional and continental scales) and prioritise populations whose loss may be irreversible and which could cause the extinction of the entire species.
   - At community level determine which vegetation types organisms perceive similarly and classify those types that function as similar habitats. Prioritise habitats/communities that offer unique guilds or guilds that contain a few or even one species that are of conservation concern.
   - At ecosystem level identify the important processes within the ecosystem and identify the biota that maintains them. Consider the relative importance of functional groups within the ecosystem. Prioritise those functional groups that would increase the resilience of the ecosystem.
4) Project future habitat patterns and processes under alternative management and climatic scenarios as far as possible. Computer simulation models may prove useful to perform trade-off analyses under different management strategies.
5) Implement preferred or experimental strategies and monitor the responses. Obtaining data for validation should be of prime concern and implemented strategies should improve our knowledge base, the effectiveness of management and ultimately the resilience of the ecosystem.
6) Consider socio and economic factors. Social factors of biodiversity are important because biodiversity measures the result of human preferences, it scale is bound by human perception and its importance is defined by human culture. We should extend biodiversity conservation to include the needs, constraints and opportunities of local people in buffer zones. Furthermore, indigenous knowledge of a system is valuable as the long-term historic experience of particular ecosystems will help gauge the resilience of the system. Biodiversity loss often involves the dilemma of regulating the natural habitat conversion process in which

naturally existing species have systematically been replaced by human chosen ones and the decision maker needs to define an optimal point at which this conversion process is halted (the optimal stopping approach).

7) Remember that habitat change is partly a natural process (for example succession).
8) We should not limit our conservation effort to preserved habitats only but should also consider sizeable areas that balance habitat loss with habitat renewal.

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