Ecological interactions and evolution
– forgotten parts of biodiversity?

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THOMAS BØHN[1] & PER-ARNE AMUNDSEN[2]

[1] Norwegian Institute of Gene Ecology, The Science Park, P.O. box 6418, 9294 Tromsø, Norway. Email: thomas@genok.org
[2] Norwegian College of Fishery Science, University of Tromsø, N-9037 Tromsø, Norway

Organisms are shaped contemporaneously by ecological processes and over long periods of time by evolution. These activities have lead to the diversification of life. But is the diversity of life all biodiversity is? We argue that biodiversity is the conclusion drawn both from the variety of life forms and the variety of processes that have shaped them. You can't talk about biodiversity in a scientifically meaningful way unless you go beyond describing it only in taxonomic terms.

Over-emphasis of taxonomic rather than process descriptions draws focus on genes and organisms rather than the dynamic interactions between them. When the environment reduces the number of species it is not just the lists of organisms that changes, but also, possibly, essential and unique interactions may be lost forever. With their loss we may lose some or all potential for generation of a new diversity of life.

Even some of our most prominent institutions dedicated to the preservation of biodiversity miss this salient point. For example, the Convention on Biological Diversity (CBD) (1993) states that:

> "'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." (http://www.biodiv.org/convention/articles.asp).

Thus, the definition given in the CBD does not explicitly state that the processes – ecological interactions and evolution – are critical elements of existing biodiversity or the earth's ability to generate biodiversity. The 'biodiversity hotspots thesis', including its revisions (Myers 1988, 1990, 2003, Myers et al. 2000), also strongly emphasizes a species-oriented biodiversity concept, even though Myers points out that other criteria than his suggestions (endemism, species richness, rarity and taxonomically unusual species) are not ruled out by the theory itself (Myers 2003). The ecological processes and interactions are both the structuring links in all food webs and a major factor in the creation of diversity, through modification of traits, segregation of niches, 'thrust and parry' arms-race, or mutually beneficial relations in symbionts, etc. by means of competition, predation, parasitism and mutualism. On an evolutionary timescale, small steps of adaptation lead to changes in individual traits, later to inclusion of new traits, inclusion of previously unused resources and habitats. In concert, these factors represent a diversification process working on all levels from DNA-molecules to kingdoms, in all organisms from viruses to large carnivores. As the process of evolution produces and maintains (parts of) the biological variation in time, it is essentially a part of the biological diversity.

Humans change the ecosystems of the world in many ways including through inappropriate resource use, pollution and introduction of non-native genotypes and organisms. Anthropomorphic changes are behind one of the largest mass extinction sagas in the history of life (Avise 2003). It is important to recognize that this not only includes biodiversity on the level of genes to ecosystems, but also the *diversity of interactions and processes* within and between organisms. Therefore, ecological processes and evolution should be included in all biodiversity contexts. In conservation strategies this would mean to preserve the processes of ecology and evolution, not only the products (like e.g. species in zoos, or DNA in gene banks). Without their natural interactive ecosystem to live in, organisms or genes will not preserve the biological diversity.

One may ask why the Convention on Biodiversity and the 'hotspots thesis' are paying little explicit attention to the ecological processes. This apparent oversight might in part be due to the abstract, immeasurable quality of a process description. A conservation strategy will always need a measure to make priorities. We understand the risk of further complicating an already difficult biodiversity concept. The inclusion of ecological processes would hardly make measurements of biodiversity easier, less ambiguous or politically more suited for nature conservation. But simplifications have their costs which we pay now or in time. By overlooking the processes that in nature are linked with the diversity of life we could over- or under-estimate our impact on biodiversity, and be in danger of making fatal mistakes in our conservation efforts.

As all types of biotopes and most particular habitats of the world already are modified by one or several disturbances like exploitation, pollution, introduced non-native species or climate change, the question of modification/disturbance should no longer be a yes- or no- question, but to *what extent* a particular habitat is modified/disturbed on a gradient of divergence from a pristine origin. Unfortunately, ecosystems free of human impact hardly exist anymore and are theoretically impossible to restore. Even low-impact ecosystems are a highly threatened category of nature. (In what sense, or when, human impact should be considered 'unnatural' is beyond the scope of this viewpoint. But you may think about it.)

Some few, scientifically interesting undisturbed (hereafter meaning minimally disturbed) exceptions may still be found from parts of tropical rainforests, arctic regions, high altitudes, deep ocean, and other unpopulated and unexploited areas. These ecosystems have a scientific value inversely proportional to their prevalence. The importance of having "reference ecosystems" where natural biological diversity and interactions can be compared to ecosystems significantly altered by *Homo sapiens* should not be underestimated. Undisturbed ecosystems are our ultimate reference point to nature itself, and enable us to study ecological patterns and processes *per se,* as well as natural system responses to climate change, pollution or introduced species and genotypes. These studies will preferably be conducted in ecosystems with few species and low complexity.

'Coldspots are cool spots'

With the 'biodiversity hotspot thesis' in mind, we would like to consider oligotrophic, species-poor systems where all or most species and interactions are native, and thus reflect the endpoint of undisturbed evolution. Should these be viewed as the lowest rank in conservation priorities or should we reckon some of their qualities, i.e. as 'natural laboratories'? By natural laboratories we mean intact ecosystems with a comprehensible complexity, i.e. where it is possible to study ecological mechanisms. This is in fact exactly what a scientific approach many times needs to render precise mechanistic knowledge from experimental laboratories, over to system-thinking in nature. Consequently, if the priority was on high precision studies of mechanisms and cause and effect relationships, coldspots would be in favour. Coldspots are cool spots, too.

In conservation biology the priority of what should be preserved is based on some selection criteria, which therefore are of outmost importance. These criteria include species richness, species turnover rates, taxonomic distinctness and ecosystem function. An interesting study shows that stressful environments with low species richness may have high beta (turnover) diversity. With other words, the same environment can be both a 'hotspot' and a 'coldspot' on biodiversity (Prize 2002). This is not a paradox; it is just a lack of focus on the biodiversity processes.

However, firstly, by using a taxonomic measure of biodiversity, we will never get to preserve sub-arctic or other species-poor ecosystems. A polluted ditch with a continuous flow of cars and trucks by its side would probably be richer in species. Luckily, in practice, many pristine coldspot areas preserve themselves as long as no gold or oil is found there. They simply cannot be exploited. The same goes for many national parks. Secondly, as long as the selection criteria overlook the ecological processes, we uphold a false view of what biodiversity is, and consequently confine the debate.

In conclusion, the immense focus on biodiversity hotspots (e.g. Kitching 2000, Myers et al. 2000, Myers 2003) tend to result in a distraction of interest away from less speciose but highly pristine systems. Biodiversity conservation is not, and should not be a sole question of the number of taxa *per se*, but rather the maintenance and function of natural ecological and evolutionary pattern and processes in systems as genuine as possible. Nature is a process.

Reference List

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