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Mini Review

Why is Biodiversity of Cardinal Importance for Public Health?

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Abstract

The reduction of biodiversity during the preceding decennia, which has been observed in a large number of taxa, not only poses a threat to public health. The increased incidence of allergic diseases (at a global scale) following the mechanism of a skewed antigen exposure, although serious enough, is only part of the perceived impaired health. A reduction of biodiversity therefore has to be considered as a major challenge to human well-being as well as to the sustainability of an ecologically balanced environment. In this review a number of mechanisms affecting biodiversity in the temperate climate zone are discussed; also a plea for a sustained focus on the importance of biodiversity in our education programs is outlined.

Keywords: Biodiversity; Allergic Diseases; Biodiversity Estimation; Insects in Food Webs; Biodiversity in Farmlands

Introduction

The underlying, causal relationship between a reduced biodiversity and the epidemical rise of allergic diseases has recently been elucidated in a paper by W. Allaerts and T.W. Chang [1]. The skewed exposure of modern humans to environmental antigens is predominantly due to the reduced diversity of peptide antigens in the domestic environment, the washed out contact with soil micro-organisms and the impoverished diversity in food antigens [1]. The combined mechanisms of skewed antigen exposure and increased hygiene appear to provide a sufficient and parsimonious explanation for the rise in allergic diseases in a highly developed and helminth-free modernized culture [1]. The effect of a general decline of biodiversity due to human activities [2], however, is a much broader challenge to public health and to human well-being altogether than previously and generally thought of. In the present mini-review, therefore, the relationship between biodiversity and public health is discussed in a broader, anthropogenic context.

Outdoor Biodiversity and Health

The importance for public health of the biodiversity of the outdoor environment depends on many aspects of modern human behavior and, therefore, is more difficult to establish than the indoor biodiversity. For instance, outdoor sporting people have far more extensive contacts with environmental antigens, breath deeper, etc. than inactive people, but it is very hard to demonstrate the effect of reduced biodiversity on public health in anthropogenic outdoor environments.

However, there is particular evidence showing that serious health risks are becoming more common, resulting from a general breakdown of ecological bionetworks and biodiversity. For instance, the health impairments occurring after contact with the Oak Processionary caterpillar *Thaumetopoea processionea*, can become very threatening in individual cases. The increased abundance of these caterpillars in moderate climate zones has been shown to result from the diminished abundance of parasite flies, parasite wasps and other insects that predate on these moths (family of *Thaumetopoeidae*). In particular, the extinction – at least in the Netherlands - of the Forest Caterpillar hunter, *Calosoma sycophanta*, has been linked to a sharp rise of the Processionary caterpillar plague in Oak woods (Figure 1).

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Fig. 1: The Oak Processionary caterpillar *Thaumetopoea processionea* has produced a sharp rise of the Processionary caterpillar plague in Oak woods of the temperate biome. The health risks induced by contact with these insects, including asthma and blindness, are caused by the urticating toxin present in the short bristles. A very important factor in the rise of this plague is the disappearance of the Forest Caterpillar hunter, *Calosoma sycophanta* (left, photograph, © 2015, Adobe Stock).

The discomforts (skin irritation) and serious health risks like asthma and even blindness, are caused by the caterpillar bristles containing a noxious, urticating toxin. The ground beetle *Calosoma sycophanta* is only one example of many disappeared insect species, not to mention the number of predator species that fed on these large insects. The complex interplay between several insect groups is for instance well studied in the case of dragonfly predation on butterfly larvae and assemblages [3]. We are only at the dawn of experiencing the ecological and health effects of these invertebrate predator species becoming extinct, and, as a consequence, of the collapse of complete compartments of the invertebrate biological food chain.

The loss of biodiversity at present is the result of a multitude of factors (called 'drivers' of change), resulting from direct or indirect human activities, including the global climate change [2]. This also holds for the progression of the Processionary caterpillar plague, at least in the Netherlands (see Figure 2). Whereas some species are expanding their biogeographical range, directly or indirectly following the rise of average temperatures, a multiple of other species is rapidly disappearing, causing the collapse of balanced ecosystems. As predicted, many more examples will be found during the forthcoming decades.

Fig. 2: Expansion of the distribution area of the Oak Processionary caterpillar in the Netherlands (data compiled from the work of Alexander P.E. van Oudenoven, et al., 2008 [21]; Wageningen University and Alterra, The Netherlands)(Insert: Local warning signal; © 2018, Biological Publishing A&O)

Biodiversity Estimation and Globalization

Biodiversity impairment, however, is not a local issue but is clearly affected by global, anthropogenic activities. The problem with the estimation of biodiversity however, is that it is quite difficult to give a technical definition of the notion of biodiversity and its constituting aspects [2]. Biodiversity is not only the species richness (the number of species in a given area), nor the diversity within species, between species and ecosystems, but above all that, it is also a complex, multidimensional interplay of factors affecting a given ecosystem [2]. For instance the temporal patterns of animal abundance, the seasonal, biogeographical distribution ranges and tropic level of groups of species (the tropic level of an organism is its level in a food chain), all have a profound influence on the biodiversity of a given ecosystem [2]. For the freshwater habitats, field investigators have developed a useful water quality index based on the presence and diversity of aquatic invertebrate macro-species [4]. Unfortunately, such key-lists and indicators of overall quality are lacking for most of the habitats, and all the more so for the whole of the planet biomes.

Although no single ecological indicator can possibly capture all the dimensions of biodiversity, it is however important to look for scientific

indicators, constructed from a multitude of ecological data, in order to enable a sound, scientifically validated rationale for solving or curing the effects of biodiversity loss. The loss of biodiversity therefore is not an academic issue for zoologists and botanists (and even the mycologists and microbiologists coming into the picture), but the global impairment of several biomes of the planet and the resulting collapse of the world 'ecosystem services' (including the reduced crops, livestock, aquaculture and also the recreational benefits) are facing our future generations.

For instance, the year 2017 has witnessed quite dramatic consequences of the global expansion of *Eucalyptus* forestry, introduced in Europe during the 18th century. Not only the introduction of non-endemic species that may cause a disruption of the original soil and micro-environmental ecosystem, but also the introduction of monoculture forests of *Eucalyptus,* may result in so-called 'killer forests' (because of the highly inflammable *Eucalyptus* oleiginous materials). Probably in combination with the rising temperatures and dryness, these ecological changes have caused hundreds of millions of economic and humanitarian damages.

At a much smaller scale - although ecologically equally devastating - may become the areal expansion of fungal parasites, not only due to global warming, but also as a direct result of a variety of human activities. For a number of years, it has been shown that these fungi threaten the survival of many amphibian taxa. The recent introduction of a new chytrid fungus species that threatens the existence of Western Palearctic salamanders, is only one of the examples studied so far [5]. Also, mysterious fungal diseases are threatening the survival of several (groups of) species of snakes (in Southern and Western USA, 2014, worldwide since 2017) [6]. Other diseases, like the *Usutu* virus (since 2001 present in Europe, large outbreak in 2012), transferred via *Culex* mosquitoes, have affected populations at large of some common European bird species like the blackbird *(Turdus merula)* [7].

Insect Biodiversity, Bird Populations and Agriculture

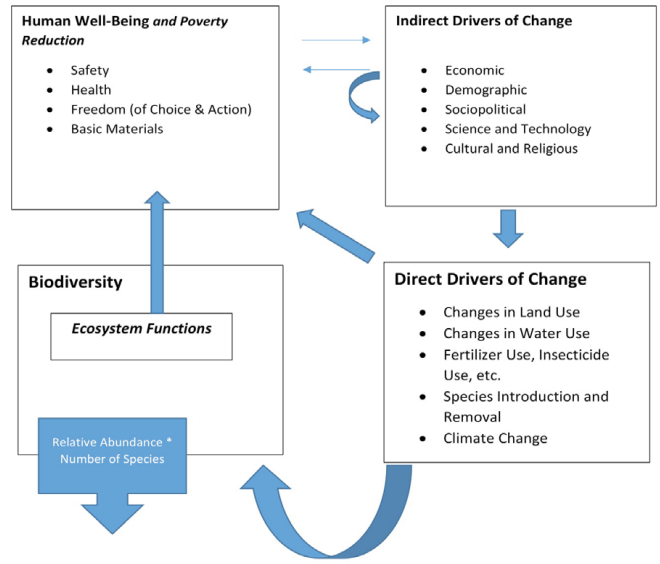
The question now is, whether it is possible to reduce the speed of biodiversity loss by taking appropriate measures and following suitable management scenarios [2]? In an international, multilevel, statistical analysis, a large consortium of European researchers have established the relationship between agricultural usage of chemical compounds [8] and the persistent reduction of biodiversity in European farmland. Moreover, for bird species like the Quail *(Coturnix coturnix*), the Corn Bunting (*Milaria calandra*), the Whinchat (*Saxicola rubetra*), the Yellow Wagtail (*Motacilla flava sp.*) and for several other bird species, the dramatic reduction in abundance is predominantly caused by the usage of insecticides and fungicides [8]. Moreover, in North-West European countries (especially in the Netherlands and parts of Northern Germany) a dramatic decrease in large insect biomass of more than 75% [9] is found to be directly linked to the usage of insecticides, fungicides and indirectly also by the use of herbicides impeding insect attraction to flowering plants [10]. It is obvious that not only the extinction of bird species like the Ortolan Bunting (*Emberiza hortulana*) – at least in the Netherlands - is harmful to a balanced ecosystem: the integral problem of pollination and crop production is at stake, when disappearance or at least decimation of the populations of flying insects takes place (Figure 3).

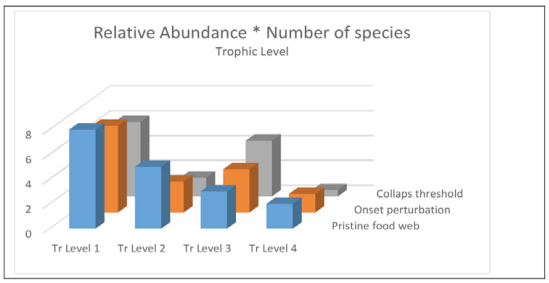
Fig. 3: Insect biodiversity as observed in western Europe during the 1970ies may well become reserved to natural musea in the near future (© 2018, Biological Publishing A&O).

We are currently working on a modeling approach for combining climate change effects on flowering, pollination and resulting biodiversity of insects and insectivorous animal species.

Biodiversity and Human Well-Being

Two dominant drivers for biodiversity change in a globalized world are the 'drivers' of land use and (fresh) water use [2]. These drivers are considered fundamental for sustained human well-being. Both are also deeply connected: literally, via the role of groundwater exchange, and, metaphorically via the total of human socio-economic activities (Fig. 4). This is most obvious in coastal lowlands and especially in regions where agricultural activities and natural conservation take place in adjacent areas. One example (out of many) is the Butrint National Park in Albania, where in the 1960ies reclaiming of large parts of marsh lands for agriculture and the resulting drainage for farmland, has caused the whole ecosystem at Butrint park to become more saline [11]. As a result, only the species adapted to saline stress were retained [11]. On the other hand, some species may also benefit or remain unaffected by increasing salinity, like exemplified by the increased abundance of the White-tailed eagle (*Haliaeetus albicilla*) in various European coastal areas.





Another example is found in the backsliding freshwater fisheries after closure of the dikes around the Southern part of the Ijsselmeer [12]. Public safety considerations for these low coastal regions and traditional economic activities like eel (*Anguilla anguilla*) fishery have been difficult to harmonize. The influx of juvenile elver from the marine to freshwater environments, and also the abundance of subadult eel populations, have dramatically decreased since the 1980ies [12]. Moreover, unexpected effects of dike enclosure on the benthic fauna may result in rapid loss of biodiversity and threaten local fisheries even further.

When traditional forms of land and freshwater use are replaced by alternative, emerging economic occupations, e.g. related to tourism, an accelerated speed of biodiversity change may be the outcome (Fig. 4). Therefore, initiatives to intensify (eco) tourism and to modernize local infrastructure should become carefully scrutinized beforehand, in order to limit the risks of biodiversity impairment. This also holds for other exponents of global trade, like the accidental importation of potentially harmful, exotic mosquitoes (*Aedes albopictus*) and their parasites, via the importation from Southern China of so-called Lucky bamboo (*Dracaena sanderiana*) for horticulture [13].

Indirect Effects of Reduced Biodiversity

Following the recommendations of the United Nations already formulated in 1992 (Convention of Rio de Janeiro), international and national political institutes should take measures to prevent further reduction of biodiversity [14]. Consequently, in April 2002, the Conference of the Parties of the Convention on Biological Diversity adopted the Johannesburg Plan of Implementation to "achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level (…)" [15]. By adopting the 2010 target, governments have explicitly recognized the value of biodiversity, and have set goals for its conservation and hold themselves accountable for the results of their measures [16].

However, the preservation of a selection of natural reserves and the protection of vertebrate species (like in the Natura 2000 program) will not be enough to counter the dramatic reduction of total biodiversity and especially not of the biodiversity in the invertebrate phyla (see examples above) and of other threatened forms of life [17].

Obviously, the huge, global decline in area of tropical rain forests threatens the health of the planet as a whole, but also, or mainly because we don't exactly know what will be lost (e.g. as potential cure or medication sources) when so many life forms become extinct. Similarly, our lack of knowledge grows when the amount of biodata becomes too vast or inaccessible; or, when certain companies and IT networks tend to obscure the ways how big data are manipulated or become spoiled by so-called 'fake news' [18].

A reduced biodiversity certainly has an alienating effect on human behavior, as was anticipated by many great thinkers of ancient and modern times (Heraclitus of Ephesus, J.-J. Rousseau, F. Nietzsche, and others). The modern life style of human culture, exhibiting an increased

dependence on man-made, anthropogenic or indoor environments, not only may further enhance the prevalence of allergic diseases, as suggested [1,19], but moreover, may further decrease the interest for a genuine, real encounter with the living environment.

Although today's initiatives are in favor of so-called Techno Garden solutions [2] - like e.g. the Green Solutions™ [20] for urban management - , increasing the livability of the 21st century megacities, these solutions may not solve the consequences of a global loss of biodiversity [21]. Sure, these Techno Garden solutions may probably help in reducing greenhouse gasses like carbon dioxide (but not methane, and others), but won't restore complex ecological food webs once destroyed. Moreover, from the viewpoint of the proximity and limited diversity of antigenic exposure, these green urban environments also will not correct the allergic diseases following the skewed antigen exposure occurring in modern life [1]. To prevent further disruption of societal cohesion, we think a different, more positive attitude towards our natural resources and companion species inhabiting the planet should be implemented in national education programs.

To conclude, further research will be needed to study the relationships between biodiversity in natural habitats and farmlands and the public health of their inhabitants.

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