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Biodiversity and Health

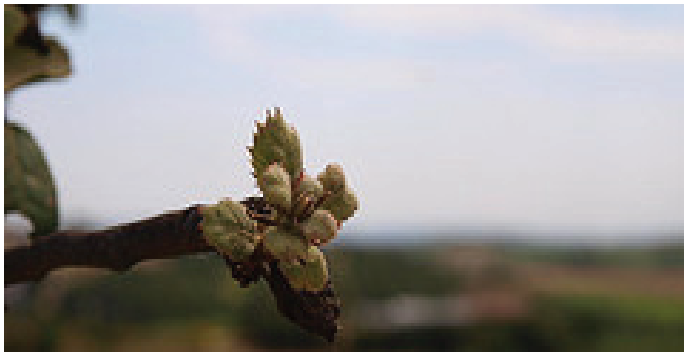
INTRODUCTION

Humans receive a wealth of benefits from ecosystems. These are described as 'ecosystem services' and include physical products, such as food and medicines, as well as useful services such as pollination of crop plants and climate regulation. Many ecosystem services do not have market prices and their economic value can be estimated only by indirect methods. There is growing recognition of the need to value ecosystem services, even if this is more difficult for regulation services than for physical products.

An emerging body of research is now uncovering a hugely important range of ecosystem services: the benefits of biodiversity for human health. In a broad sense, most ecosystem services, such as water purification and food provision, have a direct or indirect impact on human health. But ecosystems also provide more specific benefits for human health: plants and bacteria are well-recognised key sources of new medicines, and other important links include benefits for mental health, and the complex influence of the natural environment on the spread of infectious diseases.

Many links between biodiversity and human health may remain unknown. But there is a growing body of evidence that disturbances to ecosystems may have large consequences for human wellbeing. Thus protecting biodiversity – including the number of species but also the structure of communities within ecosystems – helps minimise undesirable or unintended impacts on health.

Despite global efforts to conserve biodiversity under the Convention on Biological Diversity, species are on average at greater risk of extinction than they were when targets were set in 2002. (Secretariat of the Convention on Biological Diversity, 2010) In line with international agreements to conserve biological diversity, the EU has adopted a framework for action to halt biodiversity



loss by the year 2020. In addition, the 'essential contribution to human wellbeing' of biodiversity is recognised under the EU's longer term vision for protecting and restoring biodiversity by 2050. This Future Brief explores emerging issues and recent developments in our understanding of the link between biodiversity and human health.

Key Facts: Biodiversity and Health

- More than half of all new drugs are based on or connected to natural products (Ganesan, 2008)
- Around two thirds of the agents that cause human disease are naturally transmitted from animals to humans (Diaz *et al,* 2005).
- More than half of the world's population live in urban environments (Dean *et al,* 2011). Most do not have easy access to green spaces (Hladnik and Pirnat, 2011).
- A quarter of all European species are under threat. 25% of marine mammals, 15% of terrestrial mammals, 22% of amphibians, 21% of reptiles and 12% of birds are facing extinction at the European level (EEA, 2010).

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Medicines from natural products

The natural world is a vast resource of chemical and genetic diversity which makes major contributions to medicine. Chemical compounds produced by plants, animals or microbes have been used as medicines for decades – centuries in some cases. Some of the best known examples are the penicillin antibiotics, originally discovered as natural products made by fungi, and the painkiller aspirin, developed by making chemical modifications to a substance in willow bark called salicin.

More recent advances mean that scientists are also able to make medically important compounds by making genetic changes to the organisms that produce them, or by re-engineering other organisms to produce the compounds. The anti-malarial artemisinin, an extract of sweet wormwood, can now be produced in large quantities in genetically modified yeast (Ro, *et al.* 2006) and scientists are using genetic approaches to address drug resistance problems by tweaking the biochemistry of bacteria.

Certain environmental niches, such as the deep ocean, may represent huge genetic resources with largely untapped potential for biomedical applications. For example, structurally unusual chemicals with anti-cancer activities have recently been isolated from bacteria that grow on coral reefs (Taori, *et al.* 2008).

The chemical structures produced in nature are relatively few when compared to all possible structures – an infinite number – but they have been honed through many millions of years of evolution. If lost, these biologically active structures may not be so easily accessible through computational or synthetic means. Furthermore, drug development is a slow process (between 1970-2006, only 24 natural product discoveries led directly to the approval of new drugs (Ganesan, 2008)), which highlights the urgency of protecting biodiversity now.

Nature is not just a source of new drug discoveries; it also provides inspiration for the design of novel drugs produced in the laboratory. More than half of new drugs marketed between 1981-2006 had some natural product connection, providing one compelling argument for preserving biodiversity. One example is the antibiotic SQ26,180, which was discovered in a bacterium and replaced by a synthetic mimic.

A quarter of European marine mammals are under threat

Defining *Biodiversity*

Biodiversity, as defined by the Convention on Biological Diversity (CBD), is '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' (1992).

The CBD, which came into force in 1993, is a legally binding commitment to conserve biodiversity and its adoption has had a huge impact on public and political interest in the meaning and importance of biodiversity.

Food security

Biodiversity plays a number of important roles in helping ensure humans have a secure supply of food.

For example, loss of genetic diversity within staple crops represents a threat to human health when their potential for resistance against disease, pests, drought and other natural or manmade disasters is considered. Worldwide, the diversity of agricultural crops – measured in terms of their genetic differences – has diminished rapidly in the last two decades, dwindling to a quarter of what it was in 1990 (European Commission, 2011).

Pollinators, including bees, are essential for ensuring the genetic diversity of plants, including agricultural crops. Relying on a small number of pollinator species to carry out these services is risky given recent declines and it is therefore crucial to protect a wide range, including wild pollinator populations (Potts, *et al*., 2006). In turn, many different species make up the complex ecosystems that support pollinators and careful management of natural and agricultural habitats is required to protect their biodiversity.

Biodiversity within and at the edges of agricultural land often ensures against pest infestations that could threaten food supply (Diaz, *et al*., 2005). For example, maize grown together with peanuts reduces the impact of stemborer, an important agricultural pest in central and Southern Europe, and cacao grown near to natural forests seems to suffer less from pest infestations.

Microbial biodiversity also affects food security and consequently human wellbeing. For example, soil microorganisms carry out important ecosystem services by recycling organic waste and converting nitrogen from the atmosphere into a form that plants can absorb. Their ecosystem services thus make soil more productive for agriculture and it is estimated that microbes are responsible for fixing over 140 million tonnes of nitrogen each year, the economic value of which has been estimated to be around €63 billion (Brussaard, *et al*., 2007).

Infectious diseases

The natural world has a strong influence on the transmission of diseases to humans from animals. When an infectious agent responsible for a human disease is also capable of infecting other species, these species may act as reservoirs or vectors for the disease. Poultry and livestock are important natural reservoirs for the influenza virus, for example.

Vector-borne diseases are those that are transmitted from animals to humans by an intermediate host, usually an insect vector, for example, the transmission of malaria by mosquitoes. Disturbances to biodiversity that affect reservoir and vector species will therefore affect human diseases. Deforestation, the building of dams, overfishing and agricultural development all have large impacts on ecosystems in ways that encourage changes to natural biodiversity and the structure of communities that support important reservoir and vector species. For

Case study 1: Lyme disease

Lyme disease is a bacterial disease which causes skin rashes, fever and headaches. Although treatable, persistent disease can lead to permanent damage to the brain, heart, joints and nervous system. The bacteria responsible are carried by ticks. In Europe, the geographical range of tick vectors is expanding northwards and high incidences of disease are now found in the Baltic States and Sweden, although Austria and Slovenia bear the greatest burdens (Lindgren and Jaenson, 2006).

Lyme disease is often cited as an example of the 'dilution effect'. The best host for ticks is the white-footed mouse, but the presence of a diverse community of other mammals may 'dilute' their effects on disease transmission to ticks. Laboratory-based studies and modelling approaches have found a critical role for species richness in reducing the risk of Lyme disease (Schmidt and Ostfeld, 2001).

However, results are difficult to verify in the field. A recent study suggests the modelled effect is too simplistic and that dilution or amplification of disease risk depends on more precise interactions between hosts and their contact with and resistance to ticks (Ogden and Tsao, 2009).

example, dams in Egypt and Senegal have led to outbreaks of schistosomiasis by changing the distribution of snail populations that harbour the disease (Chivian, *et al*., 2002).

Models also predict that human-induced climate change will cause the geographic range of many disease vectors to expand on a global scale (Chivian, *et al*., 2002). Although consequences for human health are currently uncertain as the factors that influence disease spread are highly complex, it is likely that, overall, climate change will exacerbate vector-borne diseases. To take the example of malaria, transmission depends not just on temperature, but on daily temperature fluctuations that affect the incubation period of the malaria parasite within the mosquito (Paaijmans, *et al*., 2010) and these are currently unpredictable under future climate scenarios.

A number of recent studies concluded that maintaining a high level of diversity among species in natural ecosystems offers protection against the emergence and spread of certain human diseases (Zaghi, *et al*. 2010). A key concept is 'the dilution effect'. Hosts carry disease which can be passed onto vectors, and in turn, onto humans. For example, mammals can carry diseases that are passed on to the parasites (e.g. ticks) that live on them; these parasites can go on to spread disease to humans. The dilution effect suggests that if there is a diverse range of hosts for a disease, the impact of the host that is best at transmitting the disease to vectors is diluted. The theory is that the meals that vectors take are spread between a variety of other hosts, many of which do not contribute to disease transmission. Studies have analysed the influence of the dilution effect in the spread of Lyme disease [see Case study 1], leishmaniasis and Chagas disease, among others.

Urban vegetation can help reduce problems caused by air pollution

Green spaces and urban biodiversity

Green spaces, such as parks and urban forests, can have a number of effects on physical and mental health. For example, trees and other vegetation in urban environments can help reduce the problems caused by air pollution. In Europe, air pollution has been calculated to be responsible for 310,000 premature deaths every year and traffic emissions in inner cities contribute significantly to this health burden. Leaves can mitigate the effects by absorbing pollutants, such as ozone - a major cause of respiratory disease.

Trees help to avoid the heat island effect and green spaces provide a more visually pleasing environment, as well as areas for exercise and leisure activities. Availability of green spaces within cities is therefore linked to mental wellbeing and physical fitness of the population, although the health benefits are difficult to quantify. The benefits of urban biodiversity must be balanced against the social and economic costs involved in maintaining urban forests [see Case study 2, Figure 1] and green spaces, along with any negative health consequences, such pollen allergies, bites and increased abundance of disease-carrying pests. In general, the multiple positive effects are considered to outweigh negative effects.

Some experts argue that because people are inseparable from their living environments, human wellbeing is closely tied to changes in the environment. Small-scale studies have found that contact with nature provides direct health benefits for conditions including attention hyperactivity disorder and depression (Faculty of Public Health, 2010). For example, a Swedish study found that a lack of access to green areas in urban environments was linked to stress-related symptoms and annoyance caused by environmental noise (Gidlofgunnarsson & Ohrstrom, 2007). More evidence is needed to determine the exact nature of the interaction between biodiversity and mental health, but even if the effects are small, activities such as walking or playing in green spaces may be attractive care options because of the low safety risks and economic costs, as compared to medical treatments.

Case Study 2: Ljubljana Green System

Figure 1 shows public green areas and parks (dots) and forests (grey and black) in the city of Ljubljana, Slovenia. Over three quarters of urban areas within the city are less than 1 km from a forest. The Ljubljana Green System combines nature preservation with benefits for the urban population, providing daily access to a green environment that is rare in cities.

Although the links between urban green areas and human health are not fully understood, a recent study (Hladnik and Pirnat, 2011) emphasised the importance of 'place attachment' – related to the feelings that people attach to green areas – in human emotional wellbeing and social cohesion. Cultural identity is also deeply rooted in the biological environment.

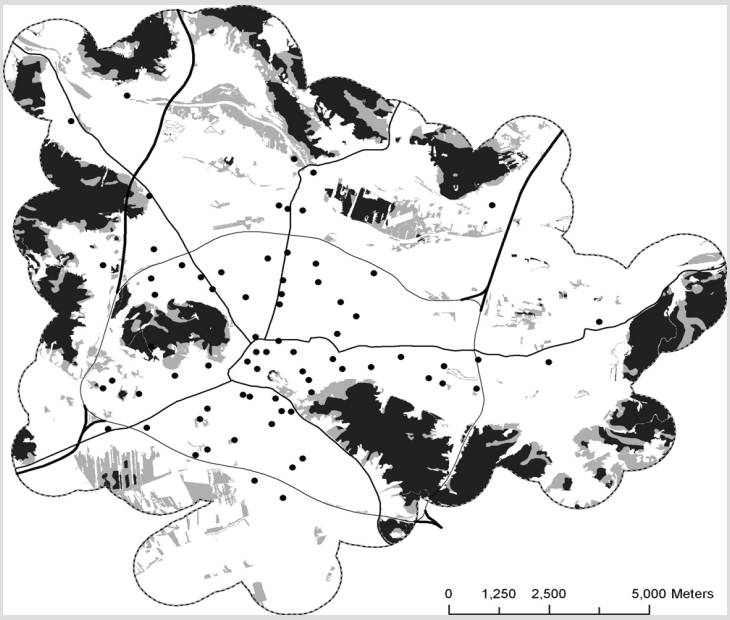

Figure 1: Public green areas and parks (dots) and forests (grey and black) in the city of Ljubljana, Slovenia.

Uncertainties and complexities

There are many uncertainties and complexities in the links between biodiversity and health. As indicated, many of the mechanisms through which human health interacts with biodiversity are difficult to appreciate and their effects to measure. Taking the example of planting trees in cities, many potential benefits exist – some local and relatively immediate, such as pollution mitigation and temperature regulation within the urban environment, and some less so, such as contribution to the global mitigation of climate change. In turn, mitigation of climate change further influences biodiversity, for instance, by helping to prevent changes in the distribution of disease hosts. Although it is impossible to accurately quantify the total health benefit that the population experiences from urban vegetation, it can be stated that urban vegetation brings multiple benefits at comparatively low cost.

Disturbances to ecosystems and biodiversity loss may affect human health in a number of complex ways. However, in some cases the negative impacts of increasing biodiversity must not be ignored. For instance, if not carefully planned, reforestation could increase the availability of habitats for disease hosts or vectors and may increase the incidence of diseases, such as leishmaniasis and malaria, especially if non-native plant species that are natural habitats for host species are introduced.

One further specific example helps illustrate the complexity of the links between health and biodiversity. In the late 1990s, outbreaks of Nipah virus in Malaysian pig farms resulted in transmission of the virus to humans, leading to one outbreak that killed around 100 people. The root cause of the outbreak is uncertain, but may have been related to changes in the feeding habits of local bats, which also carry the virus and had that year begun feeding on fruit trees on the farms. It is thought that forest fires the previous year had reduced the availability of fruit from other trees that the bats would normally feed on.

Although there are many uncertainties surrounding biodiversity and health, conserving the complex communities and ecosystems in their natural states may provide the only insurance against undesirable consequences for human wellbeing.

Policy implications

Improving scientific, political and public understanding of the connections between biodiversity and health will be key to ensuring that the consequences of biodiversity disturbances, and any resulting impacts on human health, are minimised. The value of biodiversity is increasingly recognised by international conventions and, within Europe, under policy frameworks for its conservation. However, careful management of ecosystems is required to protect human health in the future.

The following recommendations highlight just some of the key areas of concern and general principles for policy action:

- Health arguments should be incorporated into policy frameworks for action to conserve biodiversity.
- Managing specific ecosystem services does not always benefit biodiversity more broadly and may, in the long-term, have negative consequences for other ecosystem services and for human health. This should be reflected in assessments, including when possible cost-benefit analyses, of decisions and policies affecting ecosystems.
- For some ecosystem services relevant to health, benefits are best expressed in monetary terms in order to aid decision making processes. However, it may not be realistic to calculate an economic value for others.
- Singular policy measures designed to preserve ecosystem benefits to human health will be limited in their scope – a suite of different policy instruments may be required to tackle biodiversity disturbances at their root causes. Coordination between different mechanisms and at regional, national and international levels is key.
- Climate change requires special attention because it poses a threat to biodiversity across all types of ecosystems with unpredictable consequences for health.
- The links between biodiversity and human diseases are complex and require further investigation. However, an awareness of the potential risks associated with development activities, such as deforestation and afforestation, dam building and farming, is crucial and should form the basis for development decisions.
- Incorporating green spaces into urban planning combines opportunities for conserving biodiversity with health benefits to the population. Further research would help characterise the nature of the links that tie human wellbeing to biodiversity within the urban environment.

OVERVIEW

- Changes to biodiversity affect the availability of food and medicines and the incidence of many different pests and diseases.
- Human physical, psychological and emotional wellbeing are closely connected to biodiversity.
- Many links between biodiversity and human health are complex and difficult to characterise.
- Disturbances to biodiversity will have consequences for human health. These will often be unpredictable and undesirable.
- Diverse and well-coordinated policies are required to protect human health from the negative consequences of biodiversity disturbances.

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