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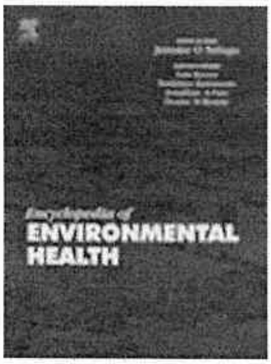

Overview of How Ecosystem Changes Can Affect Human Health

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Ecosystem changes can affect human health in several forms, most of them indirectly. Degraded ecosystems can affect water quality and availability, and cause a decrease in food production, climatic instability, poor protection against natural hazards (e.g., floods and storms), and loss of natural landscapes for aesthetic enjoyment. However, the most conspicuous and well-understood risks to health are those related to the infectious and parasitic diseases, especially those endemic in the tropical regions. The main driving forces responsible for ecosystem change today are the economic activities implemented to provide basic materials for livelihoods, such as a agriculture and animal husbandry, materials for construction (e.g., logging), and the provision of energy and water (e.g., dam building). Impacts of climate change also pose a new threat to ecosystems. These changes are taking place in a more rapid and intensive form in developing countries in the tropics.

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A0005 # Overview of How Ecosystem Changes Can Affect Human Health

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S0005 ## Introduction

P0005 AU1 Ecosystems are changing globally at an unprecedented rate. The Millennium Ecosystem Assessment (MEA) has estimated that over the past 50 years humans have changed the ecosystems more rapidly and extensively than in any comparable period of time in human history. This conclusion was based on a combination of approaches, ranging from inventories of ecosystem components to modeled results, extrapolation from case studies, information from remote sensing, and the use of indicators.

P0010 From the public health perspective, deteriorating environmental conditions are a major contributory factor to poor health and poor quality of life: it was estimated that approximately 25–33% of the global burden of disease is attributable to environmental factors. Accordingly, in the recent past, epidemiology has broadened its scope and methods to go beyond standard analytical techniques to study the interaction of both ecological and social factors responsible for human disease. Thus, we have seen the emergence of the eco-epidemiology paradigm, which examines the relations between and within localized structures organized in a hierarchy of levels, including the overarching physical environment.

P0015 At the same time, it is being increasingly recognized that environmental change plays an important role in the process of emergence and reemergence of an increasing number of infectious diseases.

P0020 Today, most of the existing conceptual frameworks for environmental health studies include ecosystem characteristics and changes as determinants of health.

P0025 This review discusses initially the ecosystem concept and the current changes in ecosystems and their services. Then it analyzes the incorporation of the ecosystem concept in public health, with case studies mostly from the ecology of infectious diseases.

S0010 ## What is an Ecosystem?

P0030 The British plant ecologist Tansley was the first to bring into use the concept of ecosystem, in 1935. Since then the ecosystem concept has evolved to become a central concept in ecology and several definitions have been proposed, all of them emphasizing the systemic, dynamic, and complex nature of these systems and the interplay between the biotic- and abiotic components.

Ecosystem became a unifying concept in ecology and P0035
environmental science in general and was considered as the key to an order underlying the complexity of nature. They exist at multiple scales in a hierarchy from regional to local and are nested or reside within each other. At larger scales, ecosystem can be evaluated based on a commonality of basic structural units.

Ecosystems always change through time scales ran- P0040
ging from daily to geological time. However, the distinction between human-induced changes and those caused by natural factors is not always easy.

Ecotones, or the transition zones between two ad- P0045
jacent ecosystems, are important from the perspective of the eco-epidemiology of focal infectious diseases. They are parts of ecosystems with high complexity and play a special functional role in the functioning of ecosystems, usually disproportionate to their areal extent. In these areas the biophysical aspects are peculiar, such as the microclimates, and the biological processes are intensified and concentrated. These include species interactions, genetic diversification and evolution, biological productivity, and movements of individuals and materials.

With regard to the components of infectious disease P0050
cycles, it has been observed that some species of ticks and mosquitoes vectors of diseases are most abundant in ecotones. In the case of the rodent species, which act as reservoirs of the lyme disease pathogen, it is known that they inhabit preferentially ecotones. Ecotones have also been identified as places where some parasites are more active in their host seeking and host switching behaviors and the result may be a concentration of pathogens in their host population at these edges.

In the past few decades, the ecosystem concept has P0055
been adopted by experts, agencies, and interest groups outside the ecological research community. This was made to provide a framework for understanding and acting on the linkages between people and their environment.

The human species, while buffered against environ- P0060
mental immediacies by culture and technology, is

ultimately fully dependent on the flow of ecosystem goods and services. Thus, the 'ecosystem approach' has been adopted by many social actors and institutions, such as the Convention on Biological Diversity. It has even recognized that "humans, with their cultural diversity, are an integral component of many ecosystems."

P0065 The same approach has been adopted by the MEA, which has acknowledged that "Ecosystems are the planet's life-support systems for all living creatures, including humans. Human biology has a fundamental need for food, water, clean air, shelter and relative climatic constancy."

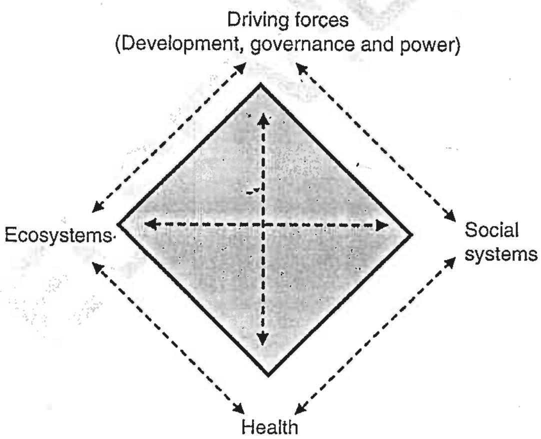
P0070 AU2 In public health too, the ecosystem approach as a conceptual and management approach was proposed as a research and development strategy to promote sustain-
AU3 able health (**Figure 1**).

P0075 According to the degree of human interference, ecosystems considered broadly can be roughly classified under three major categories:

P0080 1. *Natural ecosystems* – systems where human interference is negligible and their structure (e.g., species composition) and functioning (community interactions and abiotic cycles) are preserved to a great extent. They can be categorized into terrestrial systems (e.g., forest), freshwater, or marine systems.

P0085 2. *Managed (or cultivated) systems* – lands dominated by domesticated plant species in which at least 30% of the landscape comes under cultivation in any particular year.

P0090 3. *Built systems* – urban environments, with a high human density, usually settlements with a population of 5000 or more.



F0005 AU6 **Figure 1** Prism framework of health and sustainability. Adapted from Parkes M, Panelli R, and Weinstein P (2003) Converging paradigms for environmental health theory and practice. *Environmental Health Perspectives* 111: 669–675.

Ecosystem Services and Ecosystem Changes S0015

The relationships between human societies and ecosystems can be better appreciated through the adoption of the concept of ecosystem services. These have been defined as "the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life." P0095

The MEA has defined ecosystem services as "The benefits people obtain from ecosystems." These benefits can be direct or indirect, and many of the services are highly interlinked since they may involve different aspects of the same biological process. In short, ecosystem services occur as a result of the species interactions within the ecosystems. Some of these services are local (e.g., provision of pollinators for crops), others regional (e.g., flood control) and yet others global (e.g., climate regulation). P0100

The MEA has classified the ecosystem services under four major groups: P0105 AU4

Provisioning services – products obtained from ecosystems, including food, fuel, fiber, genetic resources, medicines, and freshwater. P0110

Regulating services – the benefits obtained from the regulation of ecosystem processes, such as air quality and climate regulation, water purification and waste treatment, and pest and infectious disease regulation. P0115

Cultural services – the nonmaterial benefits people obtain from ecosystem services through recreation, spiritual enrichment, cognitive development, and aesthetic experiences. P0120

Supporting services – those that are necessary for the production of all other ecosystem services. Their impacts on people are often indirect or occur over a very long time. These services include soil formation, photosynthesis, water-, and nutrient cycling. P0125

Many human activities rely on the stable provision of irreplaceable ecosystem services, which are synthesis of species interactions. P0130

Examples of changes in ecosystems and their services that have important global consequences for human well-being are the collapse of fisheries, alterations in water quality, shifts in regional climate, and the emergence of infectious diseases. The relations between ecosystems and ecosystem services are discussed in more detail in the next section. P0135 AU5

Human beings, unlike all other creatures, have the unique ability to affect radically the structure and functioning of ecosystems; and evidences point to a domination of Earth's ecosystems by humans, especially in terms of major changes to the global biogeochemical P0140 cycles, loss of species, water-use, and land cover changes. Unfortunately, we do not yet know enough about the structure and function of ecosystems to be able to predict how much disturbance and species loss they can undergo and still deliver ecosystem services on which we depend.

P0145 According to the MEA, most changes to ecosystems have been made to meet a dramatic growth in the demand for food, water, timber, fiber, and fuel.

P0150 These changes in recent decades have provided substantial benefits to human societies and development. However, these gains have been achieved, paradoxically, at growing costs in the form of environmental degradation and the growing of inequalities and disparities across groups of people. The degradation of ecosystem services often causes significant harm to human well-being and is sometimes the principal factor causing poverty.

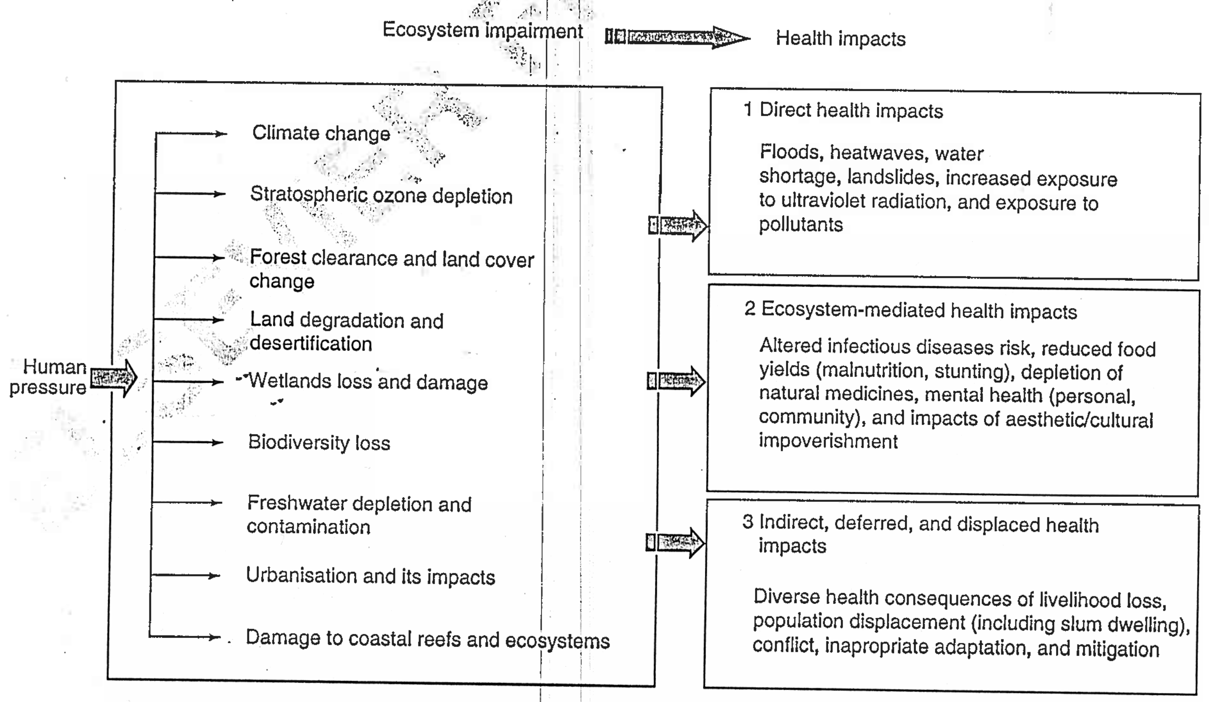
P0155 It has been estimated that approximately 60% of the ecosystem services examined by the MEA are being degraded or used unsustainably. Forests, which are important ecosystems for the provision of freshwater as well as important repositories of biological diversity and act as carbon sinks have effectively disappeared in 25 countries and another 29 have lost more than 90% of their forest cover. Deforestation in the tropics occurred at an average rate exceeding 12 million ha per year in the past two decades. More land was converted into cropland in the 30 years after 1950 than in the 150 years between 1700 and 1850. Cultivated systems now cover one-quarter of Earth's terrestrial surface. Most of the water is used (70% worldwide) for agriculture and 3–6 times as much water is held in man-made reservoirs as in natural rivers. The process of global climate change, according to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007), is already affecting the functioning of the natural ecosystems (including the distribution of their pathogens and disease vectors) and the prospects for the next decades point to important changes and species loss in these systems.

Ecohealth: Ecosystems and Human Health

A comprehensive review of the implications of changes in ecosystems to human health has been provided by the synthesis of the health components of the MEA.

P0165 Figure 2 depicts the major mechanisms through which anthropogenic pressures on ecosystems can impair human health.

P0170 The direct health impacts result from the effects of physical- and chemical hazards in the environment, produced by altered ecosystem processes and services. In the second mechanism, called 'ecosystem mediated,' health impacts involve more complex and indirect pathways, resulting from ecosystem processes. This is the case of the degradation of ecosystem services affecting food production and availability, the depletion of other ecosystem goods such as natural medicines, and also the



F0010 **Figure 2** Causal pathways through which ecosystem changes affect human health. From Corvalan CF, Hales S and McMichael AJ (2005) *Ecosystems and Human Well-Being: Health Synthesis.* Geneva: World Health Organization.

enhancement of biological hazards represented by altered populations of invertebrate vectors of infectious diseases.

P0175 The third pathway involves the effects of ecosystem changes on social-, economic- and demographic processes, such as population migration and social unrest and conflicts, as in the case of environmental refugees.

P0180 In the framework of the MEA, the following linkages between the loss of basic ecosystem services and human health outcomes are emphasized:

P0185 *Freshwater* – it is a key resource for human health and is used for growing food, drinking, washing, cooking, and for the dilution and recycling of wastes. Everyday each individual requires 20–50 l of water free from harmful chemical- and microbial contaminants. However, globally more than 1 billion people lack access to safe water supplies.

P0190 Deterioration of freshwater quality is magnified in cultivated and urban systems (high use and high pollution sources) and in dryland ecosystems (high demand for flow regulation and absence of dilution potential). Water-associated infectious diseases claim 3.2 million lives every year, approximately 6% of all deaths globally.

P0195 *Food* – in poor countries, especially in rural areas, people's health is highly dependent on the sources of local productive ecosystems for food. However, the capacity of ecosystems to provide wild food sources generally is declining because natural habitats worldwide are under increasing pressure. For example, agricultural intensification and the loss of biodiversity in agricultural landscapes can limit the availability of and access to wild foods and food plants growing as weeds. At the same time, intensive livestock production systems pose a range of risks to ecosystems and human health such as the generation of high levels of waste.

P0200 Pressure on marine ecosystems is increasing to the point where wild fisheries are near or exceeding their maximum sustainable levels of exploitation. World fish catches have been declining since the early 1990s.

P0205 More than 800 million people worldwide consume insufficient protein or calories to meet daily minimum requirements, and maternal and childhood undernutrition accounts for approximately 11% of the global burden of disease.

P0210 In the poorest countries, between one-sixth and one-quarter of the burden of disease is related to childhood and maternal undernutrition.

P0215 *Biological products* – millions of people around the world depend partially or fully on products collected from natural ecosystems for medicinal purposes; many synthetic medicines also originate from natural sources. Overharvesting is a serious issue in some regions, especially when it involves plants for botanical medicines and pharmaceuticals. The situation is frequently exacerbated by poverty, especially when harvesting wild plants is the sole source of both income and medicine for local use.

The current and future ability of countries and regions to generate novel products and industries is likely to be threatened by the loss of biodiversity and there are evidences that such losses are widespread. This directly removes the resource base for bioprospecting and declines in abundance of elements of biodiversity can reduce the ability and increase the costs of sampling.

Nutrients and waste management, processing, and detoxification – humans are at the risk of exposure to inorganic chemical compounds and persistent organic pollutants present in food and water. Well-functioning ecosystems absorb and remove contaminants as is the case of wetlands, which can remove excess nutrients from sewage runoff. Although ecosystems provide effective mechanisms for cleansing the environment for wastes, this service is now overtaxed in many settings, leading to local and sometimes global waste accumulation. Sustained increases in nitrogen- and phosphorous loading of ecosystems due to land-based human activities are contributing to the deterioration of water quality in many regions. Excessive fertilizer runoff into lakes and streams can upset the balance of nutrients in lakes and rivers, facilitating the growth of certain algal plants, including some plants that are toxic to humans. P0225 AU7

Timber, fiber, and fuel – demand for timber has led to widespread deforestation in tropical rain forests; this is associated with high rates of occupational injuries and exposure to infectious diseases with natural foci in forest systems. Forest fires and burning practices in agriculture can impair respiratory health due to inhalation of smoke. P0230

More than half of the world's population relies on solid fuel (wood, animal dung, crop stubble) for cooking and heating. As a consequence, indoor air pollution from the combustion of solid fuels is responsible for significant respiratory disease and death globally. However, in areas where the demand for wood has surpassed the local supply, the shortage of biomass fuel can lead to increased vulnerability to illness from exposure to cold and an increase in food- and waterborne diseases due to improper heating of food and water. P0235

Climate regulation – natural ecosystems play an important role in regulating climate, mainly by acting as sinks for greenhouse gases, although they can contribute to warming, if they become sources of these gases. Ecosystems also affect climate through patterns of evapotranspiration and cloud formation, water redistribution/recycling, and regional rainfall. Certain ecosystems also serve as a buffer against climate extremes, such as coral reefs and mangroves that stabilize coastlines and limit the damaging effects of storm surges. Landslides may be more likely to occur on deforested slopes following heavy rainfall. Changes in land cover affect flood frequency and magnitude. P0240

Human health may be affected indirectly by climate-induced changes in the distribution of productive P0245 ecosystems and the availability of food, water, and energy supplies. It may also be affected by economic disruption, infrastructure change, and population displacement.

P0250 Pressures on ecosystems depend on the patterns of demographic growth, development, uses of technology and lifestyle/consumption. Ecosystem changes may become important determinants of human health and the latter should be considered as an integrating concept of human well-being. This is because changes to other aspects of human well-being – security, material minimum, good social relations, and freedom – affect human health.

P0255 It is important to emphasize that the causal links between ecosystem change and human health are usually complex because often they are indirect, displaced in space and time, and dependent on a number of modifying factors.

P0260 *Regulation of infectious diseases* – this topic is addressed in detail in the next section.

S0025 Ecosystems and Infectious Diseases

P0265 Since the first quarter of the nineteenth century, when the most important microbial agents of endemic- and tropical diseases had been already identified, it became clear that societal interference in the natural environment was one of the factors that exposed people to infectious disease risk. One of the most common forms of human encroachment into ecosystems at that time was the opening of forests and other environments for the building of roads and railways. Owing to the exposure of workers and settlers to foci of infections present in the natural environments, teams of doctors and investigators were sent to these areas to elucidate the ecology and epidemiology of the infectious and parasitic diseases that affected people.

P0270 One of the pioneers in the systematic investigation of focal diseases was the Russian parasitologist E. Pavlovsky who, in the early 1930s, developed the concepts of 'nidality of infectious disease' and the corresponding scientific discipline of 'landscape epidemiology.' These, stated in a simple form, assumed that 'An infection with a *natural focus* occurs in a well-defined geographic area, in a substrate with specific ecological characteristics: climate, soil, topography, vegetation and fauna.' This was important since it established the basis for future field investigations on the relationships between ecosystems and diseases and subsidized interventions for their control.

P0275 Today, we know that most ecological systems have a unique set of infectious and parasitic diseases. According to the World Health Organization, infectious diseases account for 29 of the 96 major causes of human morbidity and mortality, representing 24% of the global burden of disease.

With the rapid changes that are taking place in ecosystems globally and also with the emergence and re-emergence of a number of infectious diseases in the past few decades, there has been a renewed interest in the study of the linkages between modifications in ecosystems and human infections. This is especially true for those disease agents that spend most of their life cycles in the environment external to the human host, such as water and vectorborne diseases, as well as disease that has animals as reservoirs.

The MEA has reviewed, among several other aspects related to ecosystems, the role of these systems in providing a service called 'regulation of infectious diseases.' This assumes that P0285

> Intact ecosystems maintain a diversity of species in equilibrium and can often provide a disease-regulating effect if any of these species are either directly or indirectly involved in the life cycle of an infectious disease and occupy an ecological niche that prevents the invasion of a species involved in infectious disease transmission or maintenance. P0290

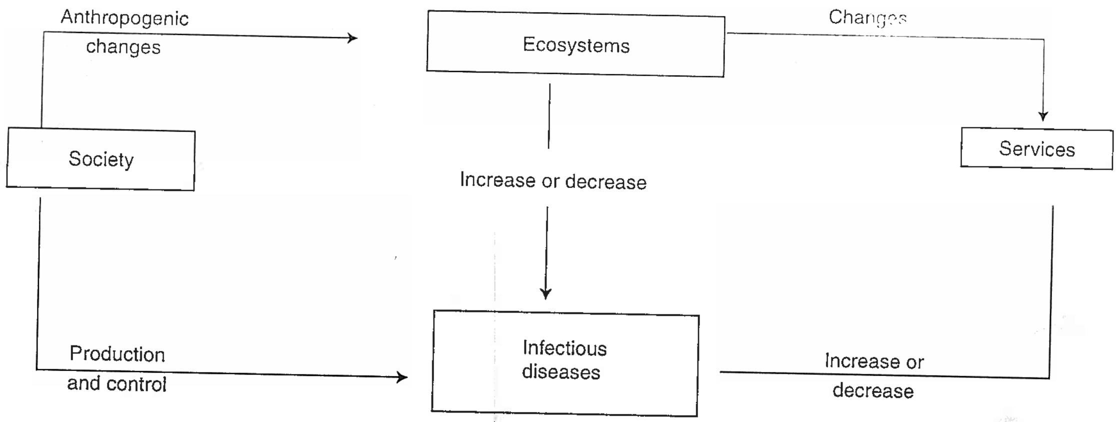
It has also reviewed how ecosystem changes can mediate the influence of anthropogenic activities in changing the epidemiological pattern of these diseases, either by reducing or increasing their incidence. The relationships between ecosystems and their services, social processes and the eco-epidemiology of human infectious and parasitic diseases is complex. Changes to ecosystems increase the risk of human infections either through biological/ecological processes or by increasing the social vulnerability of the population (e.g., through intensified behavioral exposure to vectors, malnutrition, and trauma). The linkages between social activities and their possible influence on ecosystems and their services, as determinants of human infectious disease, are depicted schematically in **Figure 3**. P0295

There is a large spectrum of human disturbances to ecosystems and their services that may change disease risk through several mechanisms. According to the MEA, these mechanisms can be summarized as follows: P0300

1. Habitat alteration P0305
2. Niche invasion and host transfer P0310
3. Biodiversity change P0315
4. Human-driven genetic changes. P0320

This is a practical classification to facilitate the understanding of the ecological processes involved, but these mechanisms often overlap or act in combination to produce synergistic effects on disease transmission. Illustrative examples of each major mechanism are briefly presented as follows: P0325

Habitat alteration – this is a common consequence of changes in land use such as deforestation for different purposes (e.g., logging and road construction) and the P0330



F0015 **Figure 3** Relationships between society, ecosystem services, and human infectious diseases. From Patz J, Confalonieri UEC, Amerasinghe FP, et al. (2005) Ecosystem regulation of infectious diseases. In: Patz J (ed.) *Conditions and Trends: Millennium Ecosystem Assessment*, pp. 391–415. Washington, DC: Island Press.

management of water bodies (e.g., dam building). These ecosystem changes may produce modifications of the biophysical environment, which favor an increase in population densities of vectors or animal reservoirs of infection. One classical example is the formation of water pools that serve as breeding sites for mosquitoes such as the anophelines that transmit malaria. This has been also observed in relation to mosquito vectors of Japanese encephalitis, which breed in irrigation channels in Asian countries.

P0335 An increase in the population of snail species that serve as intermediate hosts for the human worm *Schistosoma* sp. in water impounded in dams and irrigation channels in Africa and South America is also a good example.

P0340 *Niche invasion* – vectors and reservoirs may change
AU8 their habitats and move to managed systems where they may adapt to open niches; in this situation they may transfer pathogens from one environment to the other. In the case of humans, they get exposed to pathogens in the new habitat where they penetrate. The result of this is the possible cross-species transmission of pathogens, which is a recognized mechanism in disease emergence.

P0345 Historically, there are many examples of human encroachment into natural ecosystems and the consequent exposure to local pathogens, resulting in outbreaks of diseases, frequently zoonotic in nature. In the early twentieth century, some South American countries had initiated the process of colonization of their hinterlands, which frequently involved the construction of railways through forests and other ecological systems. Outbreaks
AU9 of cutaneous leishmaniases were common and the disease – transmitted by the bite of a sand fly – even became known as 'forest leishmaniases' in some places.

P0350 Another example, still prevalent in South America,
AU10 was the expansion of cropping areas (e.g., maize plantations) to the margins of forested areas, a habitat for rodent reservoirs of arena viruses, which have moved to farms in search of foods. As a result, outbreaks of different hemorrhagic fevers were reported in the past 50 years, such as the Junin virus in Argentina, Machupo in Bolivia, and, more recently, Guanarito in Venezuela.

In the Amazon region, where at least 180 different P0355
types of arthropod-borne viruses (arbovirus) have been described, penetration into the forest for occupational purposes or tourism may result in human arboviral infections, with varying degrees of severity (yellow fever is the most important).

With regard to the human immunodeficiency virus P0360
(HIV), it has been hypothesized that the original human infection took place in Africa when local residents had contacts with a similar virus from wild primates; in this case the mechanism of transmission seems to have been through the ingestion of bush meat.

Biodiversity changes – it means species replacement or P0365
loss (e.g., key predators) and variations in species population densities (usually of vectors or animal reservoir hosts).

Hantavirus pulmonary syndrome, caused by a P0370
rodentborne virus, may have the risk for human infections enhanced due to an increase in the population densities of its wild mammal reservoir such as the deer mouse in North America. In the southwestern United States, human outbreaks were associated with a 10– AU11
15fold increase in the mice population. This demographic change in the animal reservoir species in 1991–1993 was boosted by a natural change in the productivity of the ecosystem – and by the temporary disappearance of the local predator carnivore – caused by a long *el niño*-associated drought, followed by heavy rains.

Ecological changes that took place in southeastern P0375
Asia in 1997–1999 have facilitated the emergence of a

previously unknown zoonotic disease caused by the Nipah virus. This virus was transported for long distances from Indonesia to Malaysia by a fruit-eating bat (*Pteropus* sp.), the natural reservoir host for this virus. These mammals have been displaced from their original range by a combination of factors: land use changes (deforestation and the planting of oil palm trees) and an extreme climate (drought) caused by the *El Niño* – southern oscillation phenomenon. The bats were thus deprived of their natural habitats and food (fruits) and migrated to pig farms shaded with mango trees where they found plenty of food. In the farms they shed the viral particles in their feces, therefore, cross-infecting the pigs (amplifying hosts) and the farmers.

P0380 Another illustrative example of biodiversity changes affecting the ecology of pathogens and parasites was observed in remote areas of neotropical forests, especially in the Amazon. Newly established human settlements in natural areas have depleted the local population of vertebrate species (e.g., by overhunting), which served as food sources for the blood-sucking bat *Desmodus rotundus*, a known vector of the rabies virus. The disappearance of these vertebrates has caused the bats to shift their hosts to human beings, who were attacked in a massive and persistent way, increasing the risks of rabies infection.

P0385 Perhaps the best-known case of the linkages between biodiversity changes and the risk of human infection is given by the recently elucidated role of changes in host communities of the spirochete causing lyme disease. This zoonosis is transmitted in North America by ticks of the genus *Ixodes* sp. to a variety of host species, especially rodents. The principal reservoir, the white-footed mouse *Peromyscus leucopus*, is highly efficient at infecting ticks; whereas the other vertebrate species have a much lower ability to infect a vector, that is, have a lower 'vector competence.' When there is a decrease in host species diversity – such as has been observed in smaller forest fragments – the infection prevalence in the nymph of the vector increases and, therefore, the risk of human infection. When the host diversity is larger, the infected vector contacts are wasted on less competent host species. This has been referred to as the 'dilution effect' and may be an important determinant of the risk of infection to humans.

P0390 *Genetic changes* – it can be produced by human-driven ecosystem changes in pathogens and vectors. This has happened with the Venezuelan equine encephalitis virus following a deforestation process in southern Mexico. Protein changes in this virus have enhanced the infection of the local mosquito species that transmit the disease.

P0395 Another case of genetic change is frequently observed in the context of intensive animal production schemes (livestock and aquaculture). Under these circumstances – which cause severe impacts on the environment – antibiotics are extensively used as growth promoters and for prophylaxis, in subtherapeutic levels. This has caused, via selective pressures, the emergence of drug-resistant bacteria, some of which became a serious problem both for animal husbandry and public health.

P0400 Table 1 summarizes some of the most important cases of changes in infectious disease prevalence associated with ecosystem changes.

P0405 Two other particular situations related to environmental changes and human infectious diseases are briefly discussed: aquatic systems and urban areas.

P0410 Currently, the most globally significant change in aquatic ecosystems is eutrophication, which results from an increase in nutrient load in water, caused by pollution (by fertilizers, sewer discharges, etc.). Eutrophication can lead to changes in biogeochemistry, species diversity, and aquatic ecosystem services. Freshwater and marine systems are very productive ecosystems and, since water is an effective medium of transmission, aquatic environments can function as important reservoirs for pathogens.

P0415 Eutrophication can change biological hazards related to infections by altering host distribution and density, the virulence of pathogens, vector population densities, and toxicity. Changes in pathogens and parasites under eutrophication will depend on the species involved, the physical characteristics of the aquatic system, as well as the degree of eutrophication.

P0420 A possible consequence of the process of eutrophication in marine systems is the development of harmful algal blooms. These can affect human health either by direct toxicity or can accumulate in the food chain, especially on shellfish.

P0425 Coastal waters can be contaminated with untreated sewage and this facilitates the proliferation of microorganisms. Coastal pollution associated with high sea surface temperatures – driven by climate variability and change – has increased the risk of human infection with AU12 bacteria of the genus *Vibrio* (including the cholera agent); this is caused by bathing or the consumption of seafood.

P0430 Urban systems are peculiar environments in the sense that they are almost completely managed by society. They may be considered as artificial (or built) environments, with very few processes that are similar to the natural ecosystems. The characteristics of urban environments are constantly changing, especially through uncontrolled processes such as migration, illegal settlements, poor housing, and deficient sanitation, as is frequently observed in less-developed countries.

P0435 They also have specific 'niches' to which human disease agents and vectors have adapted. With regard to infectious diseases, two major conditions can be considered of greater importance: mosquito-transmitted pathogens and leptospirosis. The former is a heterogeneous group of infections transmitted by vectors adapted to urban structures such as sewage systems, water storage devices and roofs in houses, flower pots, T0005 **Table 1** Infectious diseases and mechanisms of potential changing incidence as related to ecosystem changes (MEA)

Disease	*Emergency mechanism (proximate)*	*Emergence driver (ultimate)*	*Geographical distribution*	*Sensitivity to ecological change*
Malaria	Niche invasion, vector expansion	Deforestation and water projects	Tropical (America, Asia, and Africa)	+ + + +
Dengue fever	Vector expansion	Urbanization and poor housing	Tropical	+ + +
Leishmaniasis	Host transfer, habitat alteration	Deforestation and agricultural development	Tropical Americas, Europe, and Middle East	+ + + +
Lyme disease	Depletion of predators, biodiversity loss, and reservoir expansion	Habitat fragmentation	North America and Europe	+ +
Chagas disease	Habitat alteration	Deforestation, urban sprawl, and encroachment	Americas	+ +
Japanese encephalitis	Vector expansion	Irrigated rice fields	Southeast Asia	+ + +
Guanarito-, Junin-, and Machupo viruses	Biodiversity loss and reservoir expansion	Monoculture in agriculture after deforestation	South America	+ +
Oropouche- and Mayaro viruses in the Amazon	Vector expansion	Forest encroachment and urbanization	South America	+ + +
Hantavirus	Variation in population density of natural food sources	Climate variability		+ +
Rabies	Biodiversity loss and altered host selection	Deforestation and mining	Tropical	+ +
Cholera	Sea surface temperature rising	Climate variability and change	Global (tropical)	+ + +
Cryptosporidiosis	Contamination by oocytes	Poor watershed management where livestock exist	Global	+ + +
Meningitis	Dust storms	Desertification	Saharan Africa	+ +
Nipah- and Hendra viruses	Niche invasion	Industrial food production, deforestation, and climate abnormalities	Australia and southeast Asia	+ + +

water-retaining plants, and trash items that accumulate rainwater (discarded tires, tins, etc.). The most important infections that proliferate under these circumstances are dengue fever in most developing countries in the tropics, malaria and yellow fever in Africa, and West Nile virus in North America. Given the accelerating process of urban growth globally – and the associated social- and environmental problems – these diseases are expected to continue to take a large toll in terms of morbidity and mortality.

P0440 Urban leptospirosis is a waterborne disease caused by a bacterium, which has the sewage rat as the main reservoir. The pathogen is eliminated through the urine of these animals and contaminates the water that invades houses under heavy rainfall and flooding conditions. Urban districts more prone to have outbreaks of leptospirosis are the low-lying poor residential districts with deficient garbage collection schemes (which facilitates the proliferation of rats) and poor drainage systems, a situation commonly observed in larger cities of the developing world.

Conclusions S0030

The changes in ecosystems that have been observed globally in the past century were responsible for the degradation of the services provided by these natural systems. This has had important adverse effects on human economy, well-being, and health. Currently, changes in natural systems are acknowledged by the public health research and practice community as one of the main determinants of human health and disease. More knowledge about the role of ecosystem changes on human health has been accumulated with regard to the infectious- and parasitic conditions when compared to other categories of diseases. P0445

Ecosystems also change due to natural processes (e.g., climate) and these, when associated with anthropic activities, can accelerate the disruption of biological regulation in these systems. This compounded mechanism is apparently responsible for the emergence and reemergence of some infectious diseases in recent decades. Although this is a global phenomenon, vulnerability to ecosystem-driven disease emergence and outbreaks is P0450 much higher in the poorer countries. This vulnerability generally results from enhanced exposures to the hazards, poor resilience of communities, and deficiencies in institutions needed for adequate responses, including the health care systems.

P0455 Prevention of human diseases driven by the degradation of ecosystem services is largely dependent on the development of capacities to tackle the complexities involved in the causation processes and also on a reduction of the structural social vulnerability to the consequences of these ecosystem changes

P0460 The acknowledgement that changes in natural systems in a global scale are important drivers of human health is also a challenge for public health research and practice. New methods are being developed to address these risks posed by nonlinear-, indirect-, and delayed effects of the health determinants resulting from ecosystem changes. This requires interdisciplinary collaboration of epidemiologists, ecologists, environmental

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Further Reading

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