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TECHNICAL INFORMATION ON BIODIVERSITY AND PANDEMICS

Note by the Executive Secretary

INTRODUCTION

1. Biodiversity and human health are closely interlinked across a wide range of scales, from the planetary to that of individual human microbiota. Ecosystems and biodiversity help regulate the planet's material and energy flows, and its responses to abrupt and gradual change.[1] Ecosystems, including food production systems, depend on a great diversity of organisms to provide the necessary services for life, including food, clean air, the quantity and quality of fresh water, medicines, spiritual and cultural values, climate regulation, pest and disease regulation, and disaster risk reduction, each of which are fundamental for human health, both mental and physical.[2] Human microbiota – the symbiotic microbial communities present in the gut, respiratory and urogenital tracts and on skin – helps regulate human health at an individual level, contributing to nutrition, aiding immune system function and preventing infections.[3] Biodiversity is thus a key environmental determinant of human health, and the conservation and sustainable use of biodiversity can benefit human health by maintaining ecosystem services and options for the future.[4]

2. There are clear links between pandemics and biodiversity.[5], [6] New pathogens usually emerge from a 'pool' of previously undescribed, potentially zoonotic microbes that have co-evolved over millions of years with their wildlife hosts.[7] An estimated 1.7 million viruses occur in mammals and water birds (the hosts most commonly identified as origins of novel zoonoses), and of these, 631,000-827,000 could have

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[3] Rook, G. A. W. (2013). Regulation of the immune system by biodiversity from the natural environment: An ecosystem service essential to health. Proc. Natl. Acad. Sci. U.S.A., 110(46): 18360– 18367. https://doi.org/10.1073/pnas.1313731110.

[4] WHO and CBD (2015) State of Knowledge Review on Biodiversity and Health, Connecting Global Priorities: Biodiversity and Human Health. https://www.who.int/globalchange/publications/ biodiversity-human-health/en/.

[5] IPBES (2020) Workshop Report on Biodiversity and Pandemics of the Intergovernmental Platform on Biodiversity and Ecosystem Services. Daszak, P., das Neves, C., Amuasi, J., Hayman, D., Kuiken, T., Roche, B., Zambrana-Torrelio, C., et al, IPBES secretariat, Bonn, Germany, DOI:10.5281/zenodo.4147318; https://wedocs.unep.org/bitstream/handle/20.500.11822/32316/ZP.pdf

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[7] Morse, S. S. et al. Prediction and prevention of the next pandemic zoonosis. The Lancet 380, 1956-1965, doi:10.1016/S0140-6736(12)61684-5 (2012)

the ability to infect humans, however, less than 0.1 per cent of viral diversity with potential zoonotic viral risk has been discovered.[8]

3. Thus, higher biodiversity may be expected to increase the *hazard* of emerging infectious diseases, because host diversity (for example of wild mammals) is correlated with the diversity of pathogens (organisms that cause disease). However, this relationship is not necessarily predictive of disease *risk* since some event is needed to convert a hazard into a risk of pathogen emergence. Such risk factors include encroachment into natural habitats and contact with wildlife. Also, paradoxically, greater host diversity may actually decrease risk of zoonotic pathogen spillover by reducing the prevalence of pathogens among a diversity of host species (though this is not always the case). Thus, efforts to minimize biodiversity loss can also reduce disease risk, mostly by reducing contact between humans and wildlife and limiting introduction of exotic species, even if these efforts maintain areas of high disease hazard through the diversity of pathogens.[9] On the other hand, there is a high potential for the emergence of novel viral pathogens from wildlife if the current trajectory of environmental change continues, and pushes closer contact among people, livestock, wildlife and the diverse assemblage of potential pathogens they are hosts to.[10]

4. Globally, there is a correlation of the emergence of new zoonoses with wildlife (mammalian) diversity, human population density and anthropogenic environmental change. There is also evidence that biodiversity loss may increase transmission of microbes from animals to people under certain circumstances. Furthermore, large scale analyses suggest that emerging disease risk may be highest in region of human-altered landscapes.[11,12,13,14,15] Although these interactions are complex and theories vary, the mechanistic drivers of risk include increased contact among wildlife, livestock and people driven by settlement and land conversion and specific high-risk activities, such as occupational exposure to wildlife, increased hunting of disease reservoirs, etc.

5. There is substantial evidence that the underlying drivers of almost all recent emerging infectious diseases (EIDs) are anthropogenic environmental changes, and socioeconomic changes, that alter contact rates among natural reservoir hosts, livestock and people, or otherwise cause changes in transmission rates.[16,17,18,19] Although some zoonotic pathogens are unable to spread from person-to-person and cause limited outbreaks, many have evolved capacity for transmission among people. These emerging infectious diseases have led to a series of outcomes including small clusters of cases, and in some cases significant outbreaks (e.g. Ebola, MERS, Lyme disease) that don't quite reach the pandemic scale.

6. The transmission ('spillover') of pathogens from wildlife to people can occur directly via high risk activities like hunting, farming and butchering wildlife (e.g. Ebola virus); or indirectly from wildlife

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through livestock to people (e.g. influenza viruses, Nipah virus). There is also evidence that the frequency of the emerging infectious disease events that lead to pandemics is increasing.[11,20.]

7. Furthermore, current demographic changes, land-use change and climate change has resulted in increased frequency of wildlife-livestock-human interactions especially in tropical and subtropical regions (low latitudes) rich in diversity of wildlife and their microbes.[21,22] On a global scale, the origins of emerging diseases correlate with environmental change (in particular land-use change), human population density and wildlife diversity.[14,16,17,39] These global changes increase the risk of repeated spillover of microbes from wildlife to people, and may explain why most emerging infectious diseases and almost all pandemics have been caused by zoonoses.[23]

8. The rising demand for meat, particularly in developed countries and emerging economies, has continued to bolster an unsustainable globalized system of intensive production that threatens biodiversity through a range of mechanisms (e.g. land-use change, eutrophication), and contributes to climate change.[24] By forming unnaturally dense assemblages of often closely related individuals, livestock farming has historically driven the emergence of pathogens within the domesticated species. However, the increasing expansion of livestock and poultry production, the increase in the size and acreage of farms, and in the number of individual animals at a site have led to increasing potential for transmission of pathogens to people, and increased prevalence of strains of antimicrobial resistant pathogens.[6,25,26,27]

9. New patterns of production and consumption and other economic incentives are also directly or indirectly linked to the drivers of biodiversity loss and disease emergence. Global demand for specific commodities such as meat, timber, wildlife products and others can be linked directly to disease emergence.

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10. The anthropogenic introduction of invasive alien species has been recognized as a cause of disease introduction to new regions[28] and transmission to new hosts including wildlife livestock and people.[29, 30, 31, 32, 33]

11. Although context-specific and scale dependant, land-use change is also a significant driver of the transmission and emergence of infectious diseases.[34,35,36,37] Land-use change leads to the loss, turnover and homogenization of biodiversity; it causes habitat fragmentation, creates novel ecosystems and promotes the expansion of human populations into landscapes where indigenous peoples and local communities have often lived. These activities create new opportunities for contact between humans and livestock with wildlife, increasing the risk of disease transmission and the emergence of pathogens.[35, 36, 37,] Even the legacy of anthropogenic disturbance can serve as a mechanistic driver of emergence by altering habitat and community structure in ways that shift disease dynamics in wildlife creating novel scenarios for pathogens to jump from wildlife to people.[39,40]

12. Although research is still scarce, climate change is projected to cause shifts in host and vector ranges, alterations to life cycles of vectors and hosts under altered climatic conditions and migration of people and domestic animals. Climate change has already driven latitudinal and elevational shifts of biomes in boreal, temperate and tropical regions[38] which has likely driven spread of certain diseases, or the expansion of some species (e.g. ticks and tick-borne disease). Temperature changes also allow occasional immigration of vectors to lead to persistence of disease.

13. Land-use change, compounded with climate change will likely create novel wildlife communities, new relationships among wildlife, human and livestock populations and increased potential for cross-species transmission.[39,40]

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14. There is significant evidence that the wildlife trade is also involved in the emergence of a range of diseases, particularly where the trade is poorly regulated, and concerns mammals or birds (the most important reservoir hosts for emerging zoonoses).[41,42,43,44,45,46]

15. The hunting, trading, butchering and preparation of wildlife for consumption has led to a significant proportion of known zoonoses, EIDs and pandemics such as Ebola virus disease, HIV/AIDS, Monkeypox, SARS and COVID-19.

16. At different stages of a trade supply chain, individual animals may be held at unnaturally high densities, which can increase the risk of microbial transmission among them. Individuals from different geographic locations are often housed together or close to each other in holding pens and containers, some in mixed species assemblages, all of which increases the opportunity for microbial transmission. Stress due to handling and the many other unnatural conditions in the trade, are likely to reduce fitness, increase the likelihood of infection (i.e. prevalence), increase the shedding of microbes and increase the risk of illness which may lead to enhanced transmission.

17. The factors that enhance likelihood of pathogen shedding, transmission, cross-species spillover and illness are intensified in live animal markets, where animals are often held for long periods of time in overcrowded conditions, with poor hygiene practices, mixed with diverse species and in close contact with large groups of people who travel regionally to purchase often live animals.[47,48,49,50,51,52,53]

18. The wildlife trade may also lead to increased human activity in rural or uninhabited regions to capture often increasingly rare species, driving new contact among people, animals and their microbes. These activities are linked in many cases to land-use change and the processes of deforestation and forest degradation, timber extraction, mining, settlement and agricultural expansion.[54,55]

19. The industrialization of wildlife trade also puts increasing pressure on indigenous peoples and local communities who have nutritional dependence on wildlife, when hunting pressure to supply the trade

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reduces populations to unsustainable levels. The increasing complexity of wildlife trade networks, including wildlife farms, live animal markets with mixed livestock and wildlife, long-distance bulk transport and international trade will likely increase future risk of disease emergence.

20. Some elements of the wildlife trade also increase the risk of emergence of diseases that affect animals farmed for food, highlighting their potential impact on food security as well as public health.

21. The loss of biodiversity due to unsustainable or unregulated wildlife trade may directly affect the health of communities who rely on wildlife as a source of food, nutrition and traditional medicine.[56] Indirect health effects may also occur due to replacement of declining species by others that may carry disease risks, or with processed food.

22. According to the World Health Organization (WHO), healthier environments could prevent almost one quarter of the global burden of disease.[57] The COVID-19 pandemic serves as a stark reminder of the delicate relationship between people and nature, demonstrating the consequential impacts of the loss and degradation of biodiversity, which increases the risk of disease transmission from wildlife to people. As pressures on ecosystems and ecological processes have escalated worldwide over the past half century due to shifts in land use and food systems, deforestation and climate change, zoonoses from wildlife have been emerging at an increasing rate.[58]

23. The geographic concentration of disease emergence events in specific high biodiversity regions suggests that a key way to control pandemic risk could be to reduce anthropogenic environmental changes specifically in emerging infectious disease hotspots. This would benefit global health, as well as conservation.[53,141,155,156] Reducing pandemic risks substantially through better management of environmental resources would cost 1-2 orders of magnitude less than estimates of the economic damages caused by global pandemics.[59]

24. Given that less than 1 per cent of known species have been utilized by people, discovery of further compounds that help develop therapeutics and diagnostic agents is highly likely.[60] Genomic advances are now bringing insights into how other species, such as bats, may resist or tolerate infections, potentially leading to mechanisms of infection control.[61,62,63] Biodiversity is therefore a fundamental resource for health.

25. Natural or naturally derived compounds account for around 75 per cent of approved antimicrobial drugs.[64] The health sector uses digital sequence information on genetic resources, for example, for the design of diagnostic tests for infectious disease agents, detection of pathogens in contaminated food for disease prevention and discovery of new therapeutics.[65]

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26. Therapeutics to fight pandemics have their origins in biodiversity and have been identified through indigenous and local knowledge and traditional medicine. Of around 270,000 known terrestrial plants, 10,000 are used medicinally.[66,67] There are many potential benefits (medicinal and others) that remain to be discovered within plant species,[68] and the genetic information present in wild species thus represents substantial 'future opportunity'. There is evidence that poor control of pandemics can impact biodiversity. The impact of disease on households can lead to food insecurity and increased reliance on and use of natural resources.[69,70,71]

27. The risk of future pandemics could also be reduced through a more integrated, cross-sectoral and biodiversity-inclusive One Health approach that builds the health and resilience of people and ecosystems, in line with the 2030 Agenda for Sustainable Development. While there is no universal definition, One Health has been broadly defined by the World Health Organization as "an approach to designing and implementing programmes, policies, legislation and research in which multiple sectors communicate and work together to achieve better public health outcomes."[72] A One Health approach recognizes that protecting the health of ecosystems is necessary in order to safeguard human health.

28. The application of One Health approaches could be further strengthened through the integration of the full range of biodiversity-health linkages in a more systematic, comprehensive and coordinated manner.[73] Essential principles of a biodiversity-inclusive approach to One Health[74] are that it should: (a) consider all dimensions of health and human well-being; (b) enhance resilience of socio-ecological systems to prioritize prevention; (c) apply the ecosystem approach;[75] (d) be participatory and inclusive; (e) be cross sectoral, multinational, and transdisciplinary; (f) operate across spatial and temporal scales; and (g) ensure social justice and gender equality. These principles emphasize the importance of assessing causes and consequences of biodiversity loss at all levels, as well as the need to strengthen the capacity of ecosystems to absorb shocks in the face of disturbance. They also promote a proactive approach, to support prevention, early warning and detection of health emergencies and disasters, and to enable timely effective response.

29. The fifth edition of the *Global Biodiversity Outlook* highlights a biodiversity-inclusive One Health transition as one of a series of fundamental shifts necessary for a realignment of people's relationship with nature and a move to sustainability.[76] Key components of the transition include to (a) reduce disease risk by conserving and restoring ecosystems; (b) promote sustainable, legal and safe use of wildlife; (c) promote sustainable and safe agriculture, including crop and livestock production and aquaculture; (d) create healthy cities and landscapes; and (e) promote healthy diets as a component of sustainable consumption.

30. These actions are mutually supportive, and also contribute to the 2030 Agenda for Sustainable Development, including the goals relating to health, equity, and ensuring gender equality. They are underpinned by respect for human rights, including the rights of indigenous peoples, local communities and

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[74] https://www.cbd.int/doc/c/8e34/8c61/a535d23833e68906c8c7551a/sbstta-21-09-en.pdf

[75] The principles of the ecosystem approach set out in CBD decision V/6 and the guidance set out in decision VII/11

[76] https://www.cbd.int/gbo/gbo5/publication/gbo-5-en.pdf

small farmers;[77] and supported by protecting and reforming, as appropriate, tenure of land and resources, equitable access to resources by poor and marginalized communities, and universal health care.

31. A biodiversity-inclusive approach to One Health would support a sustainable, healthy and just recovery from the COVID-19 pandemic[78] and also serve broader health objectives beyond the simple absence of diseases, to entail a greater focus on prevention, and strengthen the resilience of social, ecological and economic systems. Such an approach would address the common drivers of biodiversity loss, climate change, ill-health and increased pandemic risk.

32. Partial or full movement restriction for large parts of the world highlight the human value of green space in cities, essential for physical and mental health and well-being of people[79,80] and that rapid behaviour change are possible if people are convinced of its value to their health and well-being.

33. Movement and work restrictions, as well as illness-related work absences, have reduced conservation work and enforcement against illegal resource extraction [81,82] severely reduced incomes and employment, leading to increased hunting and poaching of wildlife, including of endangered species like tigers and leopards.[83]

34. Building 'green' and resilient economic systems in which the value of nature is included, will be a vital element for human health and well-being as well as environmental health. To achieve this, several international organizations and the *Global Assessment Report on Biodiversity and Ecosystem Services* issued by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services recognized the role of nature-based solutions for contributing to biodiversity conservation and overall climate change adaptation and mitigation effort in addition to providing other substantial benefits to people and nature.[84]

35. Policies that make the human-environment connection to zoonotic transmission and pandemics clear can increase support for biodiversity conservation, especially for emotive subjects like the commercial trade in wildlife and deforestation.[85]

36. Furthermore, reducing pandemic risks substantially through better management of environmental resources would cost 1-2 orders of magnitude less than estimates of the economic damages caused by global pandemics.[86] Collaboration among conservation biologists and epidemiologists should be strongly encouraged to provide scientific guidance for measures to reduce risk in these cases, such as culling of non-native species that host zoonoses, or launching disease surveillance programmes.

37. In addition, biotechnology, including synthetic biology could provide options to tackle challenges in many fields such as agriculture, health and environment. Considering the cross-cutting and integrated

[77] Including with reference to the United Nations Declaration on the Rights of Indigenous Peoples and the United Nations Declaration on the Rights of Peasants and Other People Working in Rural Areas

[78] See, for example: WHO (2020) WHO Manifesto for a healthy recovery from COVID-19 https://www.who.int/news-room/feature-stories/ detail/who-manifesto-for-a-healthy-recovery-from-covid-19; Settele, Díaz, Brondizio and Daszak (2020) COVID-19 Stimulus Measures Must Save Lives, Protect Livelihoods, and Safeguard Nature to Reduce the Risk of Future Pandemics. IPBES Expert Guest Article. https:// ipbes.net/covid19stimulus

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approach proposed through One Health, the Convention on Biological Diversity and its Cartagena Protocol have a key role to play on the safety assessment of potential solutions and technological developments that could be useful in tackling health and environmental issues. There is significant worldwide experience in conducting risk assessment for multiple purposes, including that of conducting risk assessment for the use of living modified organisms (LMOs) from many Parties to the Convention and to the Cartagena Protocol. This experience may be extremely useful in future evaluations or assessments of new developments targeting health and environmental challenges.

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