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EXECUTIVE SUMMARY OF THE STATE OF KNOWLEDGE REVIEW: CONNECTING GLOBAL PRIORITIES: BIODIVERSITY AND HUMAN HEALTH

Note by the Executive Secretary

Pursuant to paragraph 6 of decision XII/21 of the Conference of the Parties, the Executive Secretary of the Convention on Biological Diversity and the World Health Organization, in collaboration with numerous partners and experts, finalized *Connecting Global Priorities: Biodiversity and Human Health, a State of Knowledge Review*. This addendum contains the Executive Summary of the review, including its key findings. The full volume is freely available at www.cbd.int/en/health/stateofknowledge.[1] Implications of the findings for the Convention are described in UNEP/CBD/SBSTTA/19/6.

* UNEP/CBD/SBSTTA/19/1.

[1] *Connecting Global Priorities: Biodiversity and Human Health, a State of Knowledge Review* is published by the World Health Organization and the Secretariat of the Convention on Biological Diversity. The lead coordinating authors are Cristina Romanelli, David Cooper, Diarmid Campbell-Lendrum, William B. Karesh, Danny Hunter and Christopher D. Golden. The full list of authors and contributors can be found in the full report. This Summary of the *State of Knowledge Review* was prepared by the Lead Coordinating Authors in consultation with lead authors and numerous contributors to the chapters comprised in the full volume. The views expressed are those of the authors and do not necessarily represent the views of the World Health Organization or the Secretariat of the Convention on Biological Diversity or of their Parties. An earlier draft of the messages contained herein were made available for peer review and presented as UNEP/CBD/SBSTTA/18/INF/15. The full summary of the *State of Knowledge Review* was first launched in February 2015. This version was revised in August 2015 with minor typographical corrections.

PART I – Concepts, Themes and Directions

INTRODUCTION

1. **Health "is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity".** This is the definition of health by the World Health Organization. Health status has important social, economic, behavioural and environmental determinants, and wide-ranging impacts. Typically, health has been viewed largely in a human-only context. However, there is increasing recognition of a broader health concept that encompasses other species, our ecosystems and the integral ecological underpinnings of many drivers or protectors of health risks.

2. **Biological diversity (biodiversity) 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".** This definition of the Convention on Biological Diversity (Article 2) reflects different levels of biodiversity (including genetic diversity, species and ecosystems), and the complexities of biotic and abiotic interactions. The attributes and interactions of biotic and abiotic components determine ecosystem processes and their properties. The effective management of ecosystems as part of comprehensive public health measures requires that these various complex linkages and interactions be identified and understood.

3. **Biodiversity underpins ecosystem functioning and the provision of goods and services that are essential to human health and well-being.** Ecosystems, including our food production systems, depend on a whole host of organisms: primary producers, herbivores, carnivores, decomposers, pollinators, pathogens, natural enemies of pests. Services provided by ecosystems include food, clean air, and both the quantity and quality of fresh water, medicines, spiritual and cultural values, climate regulation, pest and disease regulation, and disaster risk reduction. Biodiversity is a key environmental determinant of human health; the conservation and the sustainable use of biodiversity can benefit human health by maintaining ecosystem services and options for the future.

4. **The links between biodiversity and health are manifested at various spatial and temporal scales.** At a planetary scale, ecosystems and biodiversity play a critical role in determining the state of the Earth System, regulating its material and energy flows, and its responses to abrupt and gradual change. At a more intimate level, the human microbiota – the symbiotic microbial communities present on our gut, skin, respiratory and urogenital tracts, contribute to our nutrition, can help regulate our immune system and prevent infections.

5. **Biodiversity and human health, and the respective policies and activities, are interlinked in various ways.** First, biodiversity gives rise to health benefits. For example, a variety of species and genotypes provide nutrients and medicines. Biodiversity also underpins ecosystem functioning, which provides services such as water and air purification, pest and disease control, and pollination. However, it can also be a source of pathogens, leading to negative health outcomes. A second type of interaction arises from drivers of change that affect both biodiversity and health in parallel. For example, air and water pollution can lead to biodiversity loss and have direct impacts on health. A third type of interaction arises from the impacts of health sector interventions on biodiversity and of biodiversity-related interventions on human health. For example, the use of pharmaceuticals may lead to the release of active ingredients in the environment and damage species and ecosystems, which in turn may have negative knock-on effects on human health. Protected areas or hunting bans could deny access of local communities to bushmeat and other wild sources of food and medicines with negative impacts on health. Positive interactions of this type are also possible; for example, the establishment of protected areas may protect water supplies with positive health benefits.

6. **Direct drivers of biodiversity loss include land-use change, habitat loss, overexploitation, pollution, invasive species and climate change. Many of these drivers affect human health directly and through their impacts on biodiversity.** The continued decline of biodiversity, including loss or degradation of ecosystems, is reducing the ability of biodiversity and ecosystems to provide essential life-

sustaining services and, in many cases, leads to negative outcomes for health and well-being. Ecosystem degradation may lead to both biodiversity loss and increased risk from infectious diseases. In turn, the indirect drivers of biodiversity loss are demographic change and large-scale social and economic processes. Social change and development trends (such as urbanization), poverty and gender also influence these drivers of change. Macro-economic policies and structures, and public policies that provide perverse incentives or fail to incorporate the value of biodiversity often compound the dual threat to biodiversity and public health.

7. **Human population health is determined, to a large extent, by social, economic and environmental factors.** Social determinants of health include poverty, gender, sex, age, and rural versus urban areas. Vulnerable people and groups (such as women and the poor) who tend to be more reliant on biodiversity and ecosystem services suffer disproportionately from biodiversity loss and have less access to social protection mechanisms (for example, access to health care). A social justice perspective is needed to address the various dimensions of equity in the biodiversity and health dynamic. Vulnerability and adaptation assessments are needed and should be tailored to the contexts of these populations.

8. **Women and men have different roles in the conservation and use of biodiversity and experience gender-differentiated health impacts.** Access to, use and management of biodiversity has differential gender health impacts, shaped by respective cultural values and norms, which in turn determine roles, responsibilities, obligations, benefits and rights. Institutional capacity and legal frameworks often inadequately reflect differential gender roles. There is also a lack of gender-disaggregated data on biodiversity access, use and control, and on the differential health impacts of biodiversity change.

9. **The social and natural sciences are important contributors to biodiversity and health research and policy. Integrative approaches, such as the ecosystem approach, ecohealth and One Health, unite different fields and require the development of mutual understanding and cooperation across disciplines.** Multidisciplinary research and approaches can provide valuable insights into the drivers of disease emergence and spread, contribute to identifying previous patterns of disease risk, and help predict future risks through the lens of social–ecological systems. Such challenges necessitate engagement of many stakeholders, including governments, civil society, and nongovernmental and international organizations. Integrative approaches such as these make it possible to maximize resource efficiency as well as conservation, health and development outcomes. While their value is increasingly recognized for infectious disease prevention and control, their wider applications and benefits can also extend to other areas, e.g. to the assessment of environmental health exposures and outcomes, better understanding of the health services provided by biodiversity, and of how anthropogenic changes to an ecosystem or biodiversity may influence disease risks.

PART II – Thematic areas in biodiversity and health

WATER, AIR QUALITY AND HEALTH

Access to clean water is fundamental to human health and a priority for sustainable development. Yet, almost 1 billion people lack access to safe drinking water and 2 million annual deaths are attributable to unsafe water, sanitation and hygiene. Biodiversity and ecosystems play a major role in regulating the quantity and quality of water supply but are themselves degraded by pollution.

10. **Ecosystems provide clean water that underpins many aspects of human health**. All terrestrial and freshwater ecosystems play a role in underpinning the water cycle, including regulating nutrient cycling and soil erosion. Many ecosystems can also play a role in managing pollution; the water purification services they provide underpin water quality. Mountain ecosystems are of particular significance in this regard. Many protected areas are established primarily to protect water supplies for people.

11. **Freshwater ecosystems, such as rivers, lakes and wetlands, face disproportionately high levels of threat due largely to demands on water and impacts of human activities such as dam construction and mining.** In some regions, up to 95% of wetlands have been lost and two thirds of the

world's largest rivers are now moderately to severely fragmented by dams and reservoirs. Freshwater species have declined at a faster rate than any other biome, with the sharpest decline in tropical freshwater biomes. More than one third of the accessible renewable freshwater on earth is consumptively used for agriculture, industrial and domestic use, which often leads to chemical pollution of natural water sources. Other human activity, such as mining, can also lead to bioaccumulation and biomagnification.

12. **Impaired water quality results in significant social and economic costs.** Ecosystem degradation – for example, through eutrophication caused by excessive nutrients – is a major cause of decline in water quality. Left untreated, poor-quality water results in massive burdens on human health, with the most pronounced impacts on women, children and the poor. Maintaining or restoring healthy ecosystems (for example, through protected areas) is a cost–effective and sustainable way to improve water quality while also benefiting biodiversity.

13. **Water-related infrastructure has positive and negative impacts on biodiversity, livelihoods and human health.** Altered waterways (e.g. dams, irrigation canals, urban drainage systems) can provide valuable benefits to human communities, but may be costly to build and maintain and, in some cases, increase risks (e.g. flood risk from coastal wetlands degradation). They can also diminish native biodiversity and sometimes increase the incidence of waterborne or water-related illnesses such as schistosomiasis. Approaches integrating the benefits of both physical/built and natural infrastructure can provide more sustainable and cost–effective solutions.

Air pollution is one of the most significant environmental health risks worldwide, responsible for seven million deaths in 2012. Bronchial asthma and chronic obstructive pulmonary disease are on the rise. Cardiovascular disease, immune disorders, various cancers, and disorders of the eye, ear, nose and throat are also affected by air pollution. Air pollution also affects biodiversity; it can reduce plant biodiversity and affect other ecosystem services, such as clean water and carbon storage.

14. **Ecosystems may affect air quality and have primarily beneficial outcomes for human health.** Ecosystems affect air quality in three main ways: (1) Deposition – ecosystems directly remove air pollution, through absorption or intake of gases through leaves, and through direct deposition of particulate matter on plant surfaces. (2) Changes in meteorological patterns – as ecosystems affect local temperature, precipitation, air flows, etc., they also affect air quality and pollutant emissions. By altering climate and shading buildings, ecosystems in cities alter energy use and consequent greenhouse gas emissions. (3) Emissions – many ecosystems emit volatile organic carbons (VOCs), including terpenes and arenes. While sometimes considered as pollutants, many natural VOCs play a critical role in atmospheric chemistry and air-quality regulation. Ecosystems also release pollen, sometimes associated with acute respiratory problems. Burning of vegetation is also associated with significant pollution emissions.

15. **Components of biodiversity can be used as bioindicators of known human health stressors, as well as in air- and water-quality mapping, monitoring and regulation.** Lichens are among the most widely utilized and well-developed indicators of air quality to date, and are making headway as reliable indicators for air quality regulation. The shift in species is predictable and often correlates highly with deposition measures, making lichens an accurate, cost–effective tool for mapping and monitoring. Other groups of organisms with high local biological diversity (e.g. insects and other arthropods) have high potential as bioindicators because they have the capacity to provide more fine-grained information about the state of ecosystems; they are also relatively easy to survey. Water quality can be monitored through chemical analysis but long-term trends in freshwater ecosystems are perhaps better monitored using the diversity of aquatic organisms (e.g. benthic invertebrates) as proxy for water quality and ecosystem health.

BIODIVERSITY, FOOD PRODUCTION AND NUTRITION

Agricultural productivity has increased substantially over the past 50 years, yet some 800 million people are food insecure. It is estimated that by 2050, food production will have to feed over 9 billion people,

many of whom will be wealthier and demand more food with proportionately more meat and dairy products that have greater ecological footprints.

Biodiversity underpins the productivity and resilience of agricultural and other ecosystems. However, land-use change and agriculture are dominant causes of biodiversity loss.

16. **Biodiversity in and around agricultural production systems makes essential contributions to food security and health.** Biodiversity is the source of the components of production (crops, livestock, farmed fish), and the genetic diversity within these that ensures continuing improvement in food production, allows adaptation to current needs and ensures adaptability to future ones. Agricultural biodiversity is also essential for agricultural production systems, underpinning ecosystem services such as pollination, pest control, nutrient cycling, erosion control and water supply.

17. **The loss of diversity from agroecosystems is increasing the vulnerability and reducing the sustainability of many production systems, and has had negative effects on human health.** While there have been significant increases in food production through the introduction of higher-yielding uniform varieties and breeds, loss of genetic diversity in production systems through monocropping of uniform crop varieties or animal breeds has led to instances of large production losses and, in some cases, has had significantly negative health consequences. Loss of diversity has also resulted in the reduced provision of regulating and supporting ecosystem services, requiring additional chemical inputs and creating negative feedback loops.

18. **The use of chemical inputs, particularly pesticides, has had severe negative consequences for wildlife, human health and agricultural biodiversity.** While the control of disease vectors such as malaria has generated health benefits, the use of pesticides, especially in agriculture, has led to serious environmental pollution, affected human health (25 million people per year suffer from acute pesticide poisoning in developing countries), and caused the death of many non-target animals, plants and fish. The use of agricultural biodiversity to help cope with pests and diseases and to improve soil quality is a win–win option that produces benefits to human health and to biodiversity.

19. **Pollination is essential to food security generally and to the production of many of the most nutritious foods in particular.** Pollinators play a significant role in the production of approximately one third of the global food supply. Pollination also affects the quantity, nutritional content, quality and variety of foods available. Global declines in pollinator species diversity and in the number of pollinators have critical implications for food security, agricultural productivity and, potentially, human nutrition.

20. **Increasing sustainable production and meeting the challenges associated with climate change will require the increased use of agricultural biodiversity**. Climate change is already having an impact on the nutritional quality and safety of food, and increasing the vulnerability of food-insecure individuals and households. The increased use of agricultural biodiversity will play an essential part in the adaptation and mitigation actions needed to cope with climate change, and ensuring continued sustainable supplies of healthy food, providing adaptive capacity, diverse options to cope with future change and enhanced resilience in food production systems.

21. **Agricultural practices that make improved use of agricultural biodiversity have been identified and are being used around the world.** Their potential value needs to be more widely recognized and their adoption more strongly supported through research. Support should also be provided for appropriate policy and economic regimes, and to small-scale producers. Interdisciplinary analysis and cross-sectoral collaboration (among the agriculture, environment, health and nutrition communities) is essential to ensure the integration of biodiversity into policies, programmes, and national and regional plans of action on food and nutrition security.

Malnutrition is the single largest contributor to the global burden of disease, affecting citizens of every country in the world, from the least developed to the most. Two billion people are estimated to be deficient in one or more micronutrients. At the same time, the consumption of poor-quality processed foods, together with low physical activity, has contributed to the dramatic emergence of obesity and associated chronic diseases.

22. **A diversity of species, varieties and breeds, as well as wild sources (fish, plants, bushmeat, insects and fungi) underpin dietary diversity and good nutrition.** Variety-specific differences within staple crops can often be the difference between nutrient adequacy and nutrient deficiency in populations and individuals. Significant differences in the nutrient content of meat and milk among breeds of the same animal species have also been documented. Wildlife, from aquatic and terrestrial ecosystems, is a critical source of calories, protein and micronutrients like iron and zinc for more than a billion people. Fish provide more than 3 billion people with important sources of protein, vitamins and minerals.

23. **Access to wildlife in terrestrial, marine and freshwater systems is critical to human nutrition, and global declines will present major public health challenges for resource-dependent human populations, particularly in low- and middle- income countries.** Even a single portion of local traditional animal-source foods may result in significantly increased clinical levels of energy, protein, vitamin A, vitamin B6/B12, vitamin D, vitamin E, riboflavin, iron, zinc, magnesium and fatty acids, thus reducing the risk of micronutrient deficiency. The use of wild foods increases during the traditional "hungry season" when crops are not yet ready for harvest, and during times of unexpected household shocks such as crop failure or illness. However, wildlife populations are in worldwide decline as a result of habitat destruction, overexploitation, pollution and invasive species. Conservation strategies can therefore provide significant public health dividends.

24. **The harvesting and trade of wild edible plants and animals provides additional benefits but also risks.** The collection and trade of wild foods indirectly contributes to health and well-being by providing income for household needs, particularly in less developed countries. Aggregating across numerous local-level studies, estimates of the annual value of the bushmeat trade alone in west and central Africa range between US$ 42 million and US$ 205 million (at 2000 values). This scale of economy poses important subsistence benefits. Hunting, butchering, consumption, global trade, and/ or contact in markets with other species can also present risks of transmission and spread of infectious disease.

25. **Food-based approaches are needed to help combat malnutrition and promote health.** A healthy, balanced diet requires a variety of foods to supply the full range of nutrients needed (vitamins, minerals, individual amino acids and fatty acids, and other beneficial bioactive food components). While fortification and biofortification may be cost–effective solutions to address specific nutrient deficiencies (e.g. vitamin A and iron), they cannot provide the full range of nutrients needed. Food-based approaches can be supported by a greater focus on nutrition and biological diversity in agricultural, food system, and value chain programmes and policies (compared to a dominant focus on a few staple crops), including by promoting traditional food systems and food cultures.

26. **Some dietary patterns that offer substantial health benefits could also reduce climate change and pressures on biodiversity.** The global dietary transition towards diets higher in refined sugars, refined fats, oils and meats are increasing the environmental footprint of the food system as well as the incidence of type 2 diabetes, coronary heart disease and other chronic non-communicable diseases (NCDs). Some traditional diets, such as the Mediterranean diet, and alternative vegetarian or near-vegetarian diets, if widely adopted, would reduce global agricultural greenhouse gas emissions, reduce land clearing and resultant species extinction, and help prevent diet-related chronic NCDs.

MICROBIAL DIVERSITY AND NON-COMMUNICABLE DISEASES

Non-communicable diseases are becoming prevalent in all parts of the world. Some NCDs, including autoimmune diseases, type 1 diabetes, multiple sclerosis, allergic disorders, eczema, asthma, inflammatory bowel diseases and Crohn's disease may be linked to depleted microbial diversity in the human microbiome.

27. **Humans, like all complex plants and animals, have microbiota without which they could not survive.** The human microbiome contains ten times more microorganisms than cells that comprise the human body. These occur, inter alia, on the skin, and in the gut, airways and urogenital tracts. The biodiversity of bacteria, viruses, fungi, archaea and protozoa, of which microbes are comprised, and the

interactions of microbes within the complex human microbiome influence both the physiology of and susceptibility to disease, and play an important role in the processes that link environmental changes and human health. The realization that humans are not merely "individuals" but rather complex ecosystems may be one of the major advances in our understanding of human health in recent years, with significant implications for both ecology and human health.

28. **Environmental microbial ecosystems are in constant dialogue and interchange with human symbiotic ecosystems.** Microbes from the environment supplement and diversify the composition of the symbiotic microbial communities that we pick up from mothers and family, which in turn play significant roles from a physiological perspective. Our physiological requirements for microbial biodiversity are evolutionarily determined. In addition to supplementation of the symbiotic microbiota by organisms from the natural environment, the adaptability of the human microbiota (for example, to enable digestion of novel foods) depends upon acquiring organisms with the relevant capabilities, or genes encoding necessary enzymes from the environment by horizontal gene transfer. Therefore, we need appropriate contact with potential sources of genetic innovation and diversity, and our adaptability is threatened by loss of biodiversity in the gene reservoir of environmental microbes.

29. **Several categories of organism with which we co-evolved play a role in setting up the mechanisms that "police" and regulate the immune system.** In addition to the microbiota, some other organisms (the "old infections") that caused persistent infections or carrier states in hunter–gatherer communities were always present during human evolution, and so had to be tolerated by the immune system. Therefore, they co-evolved roles in inducing the mechanisms that regulate the immune system, terminate immune activity when it is no longer needed, and block inappropriate attack on self (autoimmunity), allergens (allergic disorders) or gut contents (inflammatory bowel disease). Some of these immunoregulation-inducing organisms, for example, a heavy load of helminths, can have detrimental effects on health, and so are eliminated by modern medicine in high-income settings. This increases the importance of the immunoregulatory role of microbiota and the microbial environment in high-income settings, where these categories of organism need to compensate for loss of these "old infections".

30. **Reduced contact of people with the natural environment and biodiversity, and biodiversity loss in the wider environment, leads to reduced diversity in the human microbiota, which itself can lead to immune dysfunction and disease.** The immune system needs an input of microbial diversity from the natural environment in order to establish the mechanisms that regulate it. When this regulation fails, there may be immune responses to forbidden targets such as our own tissues (autoimmune diseases; type 1 diabetes, multiple sclerosis), harmless allergens and foods (allergic disorders, eczema, asthma, hay fever), or gut contents (inflammatory bowel diseases, ulcerative colitis, Crohn's disease). Urbanization and loss of access to green spaces are increasingly discussed in relation to these NCDs. Half of the world's population already lives in urban areas and this number is projected to increase markedly in the next half century, with the most rapid increase in low- and middle- income countries. Combined, these findings suggest an important opportunity for cross-over between health promotion and education on biodiversity.

31. **Failing immunoregulatory mechanisms, partly attributable to reduced contact with the natural environment and biodiversity, lead to poor control of background inflammation.** In high-income urban settings, there is often continuous background inflammation, even in the absence of a specific chronic inflammatory disorder. But persistently raised circulating levels of inflammatory mediators predispose to insulin resistance, metabolic syndrome, type 2 diabetes, obesity, cardiovascular disease and psychiatric disorders. Moreover, in high-income settings, several cancers rise in parallel with the increases in chronic inflammatory disorders, because chronic inflammation drives mutation, and provides growth factors and mediators that stimulate tumour vascularization and metastasis. We need to maintain the microbial biodiversity of the environment in order to drive essential regulation of the immune system.

32. **Understanding the factors that influence functional and compositional changes in the human microbiome can contribute to the development of therapies that address the gut microbiota and corresponding diseases.** Disturbances in the composition and diversity of the gut microbiota are associated with a wide range of immunological, gastrointestinal, metabolic and psychiatric disorders. The required microbial diversity is obtained from the individual's mother, from other people and animals (farms, dogs), and the natural environment. The major influences on this diversity are antibiotics, diet, and diversity loss in the environment due to urbanization and modern agricultural methods. We need to document the microbial biodiversity and the causes of diversity loss, preserve diversity, and identify the beneficial organisms and genes. These may be exploited for deliberate modification and diversification of the microbiota, which is emerging as an exciting new approach to the prevention and cure of many human diseases.

33. **Innovative design of cities and dwellings might be able to increase exposure to the microbial biodiversity that our physiological systems have evolved to expect.** In high-income settings, several very large studies reveal significant health benefits of living near green spaces. The benefits are greatest for people of low socioeconomic status. Recent data suggest that the effect is not due primarily to exercise, and exposure to environmental microbial biodiversity is a plausible explanation. This provides a strong medical rationale for increased provision of green spaces in modern cities. It might be sufficient to supplement a few large green spaces with multiple small green spaces that deliver appropriate microbial diversity.

34. **Considering "microbial diversity" as an ecosystem service provider may contribute to bridging the chasm between ecology and medicine/immunology, by considering microbial diversity in public health and conservation strategies aimed at maximizing services obtained from ecosystems.** The relationships our individual bodies have with our microbiomes are a microcosm for the vital relationships our species shares with countless other organisms with which we share the planet.

INFECTIOUS DISEASES

Infectious diseases cause over one billion human infections per year, with millions of deaths each year globally. An extensive health and financial burden is caused by both established and emerging infectious diseases. Infectious diseases also affect plants and animals, which may pose threats to agriculture and water supplies, with additional impacts on human health.

35. **Pathogens play a complex role in biodiversity and health, with benefits in some contexts and threats to biodiversity and human health in others.** The relationships between infectious pathogens and host species are complex; disease and microbial composition can serve vital regulating roles in one species or community while having detrimental effects on others. Microbial dynamics, and their implications for biodiversity and health, are multifactorial; similarly, the role of biodiversity in pathogen maintenance is not fully understood.

36. **Human-caused changes in ecosystems, such as modified landscapes, intensive agriculture and antimicrobial use, are increasing the risk and impact of infectious disease transmission.** Approximately two thirds of known human infectious diseases are shared with animals, and the majority of recently emerging diseases are associated with wildlife. Vector-borne diseases also account for a large share of endemic diseases. Increasing anthropogenic activity is resulting in enhanced opportunities for contact at the human/animal/environment interface, which is facilitating disease spread, and through changing vector abundance, composition, and/or distribution. Changes in land use and food production practices are among the leading drivers of disease emergence in humans. At the same time, pathogen dynamics are changing. While pathogen evolution is a natural phenomenon, factors such as global travel, climate change and use of antimicrobial agents are rapidly affecting pathogen movement, host ranges, and persistence and virulence. Beyond direct infection risks for humans and animals, such changes also have implications for food security and medicine.

37. **Areas of high biodiversity may have large numbers of pathogens, yet biodiversity may serve as a protective factor for preventing transmission, and maintaining ecosystems may help to reduce**

exposure to infectious agents. While the absolute number of pathogens may be high in areas of high biodiversity, disease transmission to humans is mostly determined by contact and, in some cases, biodiversity may serve to protect against pathogen exposure through host species competition and other regulating functions. Limiting human activity in biodiverse habitats may reduce human exposure to high-risk settings for zoonotic pathogens, while serving to protect biodiversity.

38. **Infectious diseases threaten wild species as well as the people that depend on them.** The health burden of infectious diseases is not limited to humans and domestic species; infectious diseases pose a threat to biodiversity conservation as well. Pathogen spillover can occur from one wild species to another, potentially causing an outbreak if the species or population is susceptible to the pathogen. Similarly, diseases of domestic animals and humans can also be infectious to wild species, as seen with the local extinction of African wild dog populations following the introduction of rabies virus from domestic dogs. Ebola virus has also been recognized as causing severe declines in great ape populations, including the critically endangered wild lowland gorilla troops. Past Ebola outbreaks in great apes have preceded human outbreaks, suggesting a sentinel or predictive value of wildlife monitoring to aid in early detection or prevention of human infections. In addition to the direct potential morbidity and mortality threats from infectious diseases to the survival of wild populations, infection-related population declines may compromise the health-benefiting ecosystem services that wildlife provides. For example, major declines recently seen from fungal infections associated with White Nose syndrome in North American bats and chytrid in amphibians may affect the pest control functions that these animals provide.

39. **The rapidly growing number of invasive species causes significant impacts on human health, and this effect is expected to further increase in the future, due to the synergistic effects of biological invasions and climate change.** Preventing and mitigating biological invasion is not only important for protecting biodiversity, but also for protecting human health. Through trade and travel, the number of invasive species is increasing globally as a consequence of the globalization of economies, and the increase is expected to intensify in the future due to synergistic effects with climate change. Invasive species not only impact biodiversity but also affect human health causing diseases or infections, exposing humans to bites and stings, causing allergic reactions, and facilitating the spread of pathogens.

MEDICINES: THE CONTRIBUTION OF BIODIVERSITY TO THE DEVELOPMENT OF PHARMACEUTICALS

Many of the diseases that afflicted or killed most people a century ago are largely curable or preventable today thanks to medicines, many of which are derived from biodiversity. Yet, in many instances, the very organisms that have given humanity vital insights into human diseases, or are the sources of human medications, are endangered with extinction because of human actions.

40. **Biodiversity has been an irreplaceable resource for the discovery of medicines and biomedical breakthroughs that have alleviated human suffering.** Drugs derived from natural products may perhaps be the most direct and concrete bond that many may find between biodiversity and medicine. Among the breakthroughs that dramatically improved human health in the twentieth century, antibiotics rank near the top. The penicillins as well as nine of the thirteen other major classes of antibiotics in use derive from microorganisms. Between 1981 and 2010, 75% (78 of 104) of antibacterials newly approved by the United States Food and Drug Administration (USFDA) can be traced back to natural product origins. Percentages of antivirals and antiparasitics derived from natural products approved during that same period are similar or higher. Reliance upon biodiversity for new drugs continues to this day in nearly every domain of medicine.

41. **For many of the most challenging health problems facing humanity today, we look to biodiversity for new treatments or insights into their cures.** Most of the medicinal potential of nature has yet to be tapped. Plants have been the single greatest source of natural product drugs to date, and although an estimated 400 000 plant species populate the earth, only a fraction of these have been studied for pharmacological potential. One of the largest plant specimen banks, the natural products repository at the National Cancer Institute, contains ~60 000 specimens, for instance. Other realms of the living world, especially the microbial and marine, are only beginning to be studied and hold vast potential for new

drugs, given both their diversity and the medicines already discovered from them. Many species, which could be potential sources of medicines, are threatened by extinction.

42. **Greater even than what individual species offer to medicine through the molecules they contain or traits they possess, an understanding of biodiversity and ecology yield irreplaceable insights into how life works, which bear upon current epidemic diseases.** Consider the multiple pandemics that have resulted from antibiotic resistance. Human medicine tends to use a paradigm for treating infections unknown in nature, which is treating one pathogen with one antibiotic. Most multicellular life (and a good share of single cellular life) produces compounds with antibiotic properties but never uses them in isolation. Infections are attacked, or more often prevented, through the secretion of several compounds at once.

TRADITIONAL MEDICINE

Millions of people rely on traditional medicine that is dependent on biological resources, well-functioning ecosystems and on the associated context-specific knowledge of local health practitioners. In local communities, health practitioners trained in traditional and non-formal systems of medicine often play a crucial role in linking health-related knowledge to affordable health-care delivery.

43. **Traditional medical knowledge spans various dimensions relating to medicines, food and nutrition, rituals, daily routines and customs.** There is no single approach to traditional medical knowledge. Traditional knowledge is not restricted to any particular period in time, and constantly undergoes re-evaluation based on local contexts. Some traditional medical systems are codified, and some even institutionalized. They range from highly developed ways of perception and understanding, classification systems (local taxonomies) to metaphysical precepts. Links to geography, communities, worldviews, biodiversity and ecosystems based on specific epistemologies make traditional health practices diverse and unique. By extension, the level of expertise is heterogeneous and therefore internal validation methods differ substantially, despite an underlying philosophical principle of interconnectedness of the social and natural worlds.

44. **Medicinal and aromatic plants, the great majority of which are sourced from the wild, are used in traditional medicine and also in the pharmaceutical, cosmetic and food industries.** The global use of and trade in medicinal plants and other biological resources, including wildlife, is high and growing. Plants used in traditional medicine are not only important in local health care, but are also important for innovations in health care and associated international trade; they enter various commodity chains based on information gathered from their use in traditional medical pharmacopeia. Globally, an estimated 60 000 species are used for their medicinal, nutritional and aromatic properties and, every year, more than 500 000 tons of material from such species are traded. It is estimated that the global trade in plants for medicinal purposes reaches a value of over US$ 2.5 billion and is increasingly driven by industry demand.

45. **Threats to medicinal plants, animals and other medicinal resources are increasing. Wild plant populations are declining – one in five species is estimated to be threatened with extinction in the wild.** Animals (amphibians, reptiles, birds, mammals) used for food and medicine are more threatened than those not used. Overharvesting, habitat alteration and climate change are among the major drivers of declines in commercially important wild plant resources used for food and medicinal purposes. These pose a threat both to the wild species and to the livelihoods of collectors, who often belong to the poorest social groups. There is a clear need to continue efforts at developing assessment methods and indicators for conservation and sustainable use.

46. **Sustainable use of medicinal resources can provide multiple benefits to biodiversity, livelihoods and human health, in particular, relating to their affordability, accessibility and cultural acceptability.** Sustainable medicinal resource management for both captive breeding and wild collection is crucial for the future of traditional medicine. This involves all stakeholders, including conservationists, the private health-care sector, medical practitioners and consumers. Appropriate market-based instruments to enable sustainable and responsible utilization of resources in traditional medicine are required. Value

chains of traditional medicines can be simple and local, or global and extremely complex. Some resources have one or a few specific uses while others are used in many different products and markets. In many cases, the people who harvest these resources have little knowledge of the subsequent uses and value. Ensuring equitable economic returns to local communities by promoting value-added activities at the local level could help to harness the knowledge of local communities on medicinal resources and promote their sustainable use.

47. ***Sui generis* models may need to be developed and applied to secure the rights of indigenous peoples and local communities over traditional medical knowledge and related resources.** Traditional medical knowledge is often an inspiration for industrial research and development (R&D) processes in bioresource-based sectors, necessitating mechanisms to secure appropriate attribution and sharing of rights and benefits with knowledge holders, as set out in the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from their Utilization. It would be beneficial to strengthen and promote existing tools, databases and registers, and intellectual property rights that are sensitive to community values.

48. **Improving public health outcomes and achieving the objectives of "Health for All" and "Good Health at Low Cost" should include traditional medical care, and the development of appropriate integrative methodologies and safety standards within and across medical systems.** More than one third of the population in many developing countries do not have access to modern health care, and are dependent on traditional medical systems. There is high patronage of and dependence on traditional health practitioners to provide care to people with inadequate access to modern health infrastructure or with a preference for traditional systems. Pluralistic approaches that integrate natural resources and medical knowledge, and are sensitive to local priorities and contexts, can enable better health outcomes. This implies the need to develop cross-sectoral, cost–effective measures to test the safety, efficacy and quality of traditional medicines, integrate traditional healers in the health-care system through appropriate accreditation practices and processes, promote cross-learning between different knowledge systems and disciplines through participatory, formal and informal learning processes to supplement current practices in a culturally sensitive way.

BIODIVERSITY AND MENTAL, PHYSICAL AND CULTURAL WELL- BEING

It is well established that biodiversity is a central component of many cultures and cultural traditions, and there is evidence that exposure to nature and more biodiverse environments can also provide mental and physical health benefits. Over half of the world's population lives in cities and that proportion is increasing. There is a rising trend for people, especially from poor communities, to be separated from nature and be deprived of the physical, physiological and psychological benefits that nature provides.

49. **The interaction with nature – including domestic animals, and wild animals in wild settings – may contribute to treatments for depression, anxiety and behavioural problems, including for children.** Exposure to nature is important for childhood development, and children who grow up with knowledge about the natural world and the importance of conservation may be more likely to conserve nature themselves as adults. Conversely, it has been stipulated that children in developed countries increasingly suffer from a "nature-deficit disorder", due to a reduction in the time spent playing outdoors as a result of increased use of technology and parental/societal fears for child safety. On the other hand, some research has suggested that some children, particularly those from urban areas, are fearful of spending time in certain natural habitats (woodland and wetland) owing to perceived threats from isolation, wild animals or the actions of other people.

50. **Exposure to green spaces may have positive impacts on mental health.** Depression accounts for 4.3% of the global burden of disease and is among the largest single causes of disability worldwide, particularly among women. Some studies of populations in developed countries have suggested that adults exposed to green spaces report fewer symptoms and a lower overall incidence of certain diseases than others, and that the relationship is strongest for mental illnesses such as depression, anxiety and stress. Similarly, beneficial mental health impacts have been associated with greater exposure to microbial

diversity. Other research has indicated that experience of nature can reduce recuperation times and improve recovery outcomes in hospital patients.

51. **Access to natural green spaces can increase levels of physical activity with benefits for health.** The benefits of physical activity may include a reduced risk of several NCDs, as well as improved immune function. It may also provide mental health benefits, and facilitate social connections and independence. Among populations for which access to open countryside is limited, particularly those in poorer inner-urban areas of large cities, access to green spaces in the urban environment can encourage regular physical activity and improve life expectancy. It has also been suggested that health benefits may be more significantly attributable to enhanced exposure to environmental microbes in green spaces. There is evidence that biodiversity encourages the use of urban green spaces. Efforts to develop biodiverse settings, including wildlife-rich gardens, can also boost physical activity in sedentary and vulnerable patients and residents. While the potential that green spaces can offer for promoting and enhancing physical fitness is still not fully recognized, there is a growing interest in many countries to promote and enhance "green and blue infrastructure" (terrestrial and aquatic environments) within tourism, public health and environmental policies.

52. **Biodiversity is often central to cultures, cultural traditions and cultural well- being.** Species, habitats, ecosystems and landscapes influence forms of music, language, art, literature and dance. They form essential elements of food production systems, culinary traditions, traditional medicine, rituals, worldviews, attachments to place and community, and social systems. Use of the WHO Quality Of Life Assessment (devised to determine an individual's quality of life in the context of their culture and value systems) has shown that the environmental domain is an important part of the quality-of-life concept. Socioecological production landscapes (e.g. Satoyama in Japan) or conservation systems (e.g. sacred groves, ceremonial sites) or therapeutic landscapes (e.g. sacred healing sites), and related traditional knowledge practices can have therapeutic value and contribute to health and well-being.

53. **Significant changes to local biodiversity or ecosystem sustainability can have specific and unique impacts on local community health, where the physical health of a community is directly influenced by or dependent upon ecosystem services, particularly regarding access to diverse food and medicinal species.** Indigenous and local communities often act as stewards of local living natural resources based on generations of accumulated traditional knowledge, including knowledge of agricultural biodiversity, and biodiversity that supports traditional medicinal knowledge. Where local traditions and cultural identity are closely associated with biodiversity and ecosystem services, declines in the availability and abundance of such resources can have a detrimental impact on community well-being, with implications for mental and physical health, social welfare and community cohesion.

54. **While many community-specific links between health, culture and biodiversity have been documented and measured, much of the evidence for a more universal relationship is relatively sparse beyond anecdotal accounts.** However, there is growing recognition of the role of biodiversity and ecosystem services in shaping broad perspectives of quality of life.

IMPACTS OF PHARMACEUTICAL PRODUCTS ON BIODIVERSITY AND CONSEQUENCES FOR HEALTH

Antibiotics and other pharmaceuticals are essential for human health and also play an important role in veterinary medicine. However, the release of active pharmaceutical ingredients (APIs) into the environment can be harmful to biodiversity, with negative consequences for human health.

55. **The release of pharmaceuticals and APIs into the environment can have an impact on biodiversity, ecosystems and ecosystem service delivery and may, in turn, negatively impact human health.** A range of pharmaceuticals, including hormones, antibiotics, antidepressants and antifungal agents, have been detected in rivers and streams across the world. Most pharmaceuticals are designed to interact with a target (such as a specific receptor, enzyme or biological process) in humans and animals to deliver the desired therapeutic effect. If these targets are present in organisms in the natural environment, exposure to some pharmaceuticals might be able to elicit effects in those organisms. Pharmaceuticals can

also cause side-effects in humans and it is possible that these and other side-effects can also occur in organisms in the environment. During the life cycle of a pharmaceutical product, APIs may be released into the natural environment, including during the manufacturing process via human or domestic animal excretion into sewage systems, surface water or soils, when contaminated sewage sludge, sewage effluent or animal manure is applied to land. APIs may also be released into the soil environment when contaminated sewage sludge, sewage effluent or animal manure is applied to land. Veterinary pharmaceuticals may also be excreted directly to soils by pasture animals. Measures are needed to reduce this environmental contamination.

56. **Antibiotic and antimicrobial use can alter the composition and function of the human microbiome, and limiting their use would provide biodiversity and health co-benefits.** Antibiotic use can dramatically alter the composition and function of the human microbiome. Although much of the microbiome and its relationship to its host remains unexplored, what is already apparent is that changes to the variety and abundance of various microorganisms, as can occur with antibiotic use, may affect everything from the host's weight and the risk of contracting autoimmune disease, to susceptibility to infections. The microbiome may also be able to affect mood and behaviour. The use of antibacterial products and antibiotics may also be linked to the increase in chronic inflammatory disorders, including allergies such as asthma and eczema, because they reduce exposure to microbial agents that set up the regulation of the immune system. Limiting the use of antimicrobial agents could provide potential co-benefits for human health and biodiversity, reducing chronic inflammatory diseases through a healthy and more diverse human microbiota while also reducing the risk of emerging disease from antibiotic-resistant strains and the potential impacts of antibiotics on ecosystems more broadly.

57. **The inappropriate use of antibiotics in plants, animals and humans has cultivated numerous highly resistant bacterial strains.** In some instances, resistant bacterial strains cannot be effectively treated with any currently available antibiotic. Promoting the responsible and prudent use of antibiotics and antimicrobials in human health, agricultural practices and food production systems can achieve public health and biodiversity co-benefits. Poorly managed industrial agricultural practices contribute to ecosystem degradation, air and water pollution, and soil depletion, and rely heavily on the inappropriate use of antibiotics for both therapeutic as well as prophylactic (growth promotion) use. This may lead to environmental dispersion of antimicrobial agents, antibiotic resistance, and reduced efficacy in subsequent use for medical or food production applications. From a health perspective, the use of antimicrobials and antibiotics may disrupt microbial composition, including the relationships between hosts and their symbiotic microbes, and lead to diseases. At the same time, antibiotic resistance in any environment can pose serious threats to public health. Aside from its potential to cultivate resistance, antibiotic use also carries the potential to disrupt symbiotic bacterial composition.

58. **Endocrine-disrupting chemicals found in pharmaceutical products and in many household, food and consumer products, have adverse effects on the health of terrestrial, freshwater and marine wildlife, and of humans.** The use of contraceptive hormones and veterinary growth hormones has been linked to endocrine disruption and reproductive dysfunction in wildlife. They also affect both male and female human reproduction, and have been linked to prostate cancer, and neurological, endocrinological, thyroid, obesity, and cardiovascular problems. Biodiversity has also been a good monitor for some of these human health problems. In some cases, health specialists were alerted to the scale of a potential problem through changes originally recorded in wild fish populations.

59. **The inappropriate use of some non- steroidal anti-inflammatory drugs and other veterinary drugs threatens wildlife populations.** For example, in the 1980s, populations of three previously abundant vulture species in South Asia were reduced to near extinction due to the use in livestock of diclofenac, residues of which remained in the carcasses of treated animals. This led to negative impacts on human health through the spread of diseases by feral dogs, as access to carcasses increased, especially among communities who rely on vultures to consume their dead. Following bans on the use of diclofenac and its replacement by meloxicam, the decline in vulture populations has slowed and some show signs of

recovery in the region. Without proper risk assessment and regulation, the marketing and use of pharmaceuticals used for livestock may continue to pose threats to human and wildlife health.

PART III: Cross-cutting issues, tools and ways forward

GLOBAL ADAPTATION TO CLIMATE CHANGE AND DISASTER RISK REDUCTION

60. **Climate change is already negatively impacting on human health and these impacts are expected to intensify.** The direct effects of climate change on health may include stroke and dehydration associated with heat waves (particularly in urban areas), negative health consequences associated with reduced air quality and the spread of allergens. Effects are also mediated through the impacts on ecosystems and biodiversity. Such effects may include decreased food production and changes in the spread of climate-sensitive waterborne and water-related, foodborne and vector-borne diseases. There may be synergistic effects of climate change, land-use change, pollution-invasive species and other drivers of change, which can amplify the impacts on both health and biodiversity.

61. **Climate change will not only affect agricultural production systems but also the nutritional content of foods, and the distribution and availability of fisheries.** Changes in temperature and precipitation patterns will have complex effects, but the net effect on food production will be negative. While rising levels of atmospheric carbon tend to increase productivity, they will lead to reduced concentrations of minerals such as zinc and iron in crops such as wheat and rice. With regard to marine fisheries, while there would be increased productivity at high latitudes, there will be decreased productivity at low/mid latitudes, affecting poor developing countries.

62. **Disasters may be precipitated by impacts on critical ecosystems or the collapse of essential ecosystem services.** Disasters may include disease epidemics, flooding, storms, extreme weather and wildfires. Some of these may be precipitated by ecosystem disruption. There has been an increase in the frequency and intensity of some climate-related extreme events in recent years. Ecosystem degradation can increase the vulnerability of human populations to such disasters. New environmental impacts often occur during and after an emergency with an increased demand for certain natural resources, which can place additional stress on specific ecosystems (such as groundwater resources) and their functioning.

63. **Competition over access to ecosystem goods and services can contribute to, and become a cause of, conflict, with consequences that can negatively impact ecosystem goods and services in both the short- and long term.** Greater recognition needs to be given to the potential positive role that conservation and ecosystem management can play in conflict prevention and resolution and peace-building, while the converse also holds good.

64. **The creation of disaster-resilient societies is increasingly tied to and dependent upon resilience in ecosystems, and sustainability and security in the flow and delivery of essential ecosystem goods and services.** This includes not only those goods and services directly associated with resilience to immediate disaster impacts, but also those that normally support communities and the wider society. Long-term health status is an important indicator of the resilience of a community – as a marker for capacity to overcome or adapt to health challenges and other social, environmental and economic pressures. Communities whose ability to overcome current challenges are affected by ecosystem degradation at the time of a disaster event – natural or human induced – are likely to be significantly more vulnerable to disasters than communities with greater ecological security.

65. **Biodiversity helps to improve the resilience of ecosystems, contributing to adaptation to climate change and moderating the impacts of disasters.** Ecosystem-based adaptation and mitigation strategies are needed to build the resilience of managed landscapes and jointly reduce the vulnerabilities of ecosystems and communities reliant upon them for their health, livelihoods and well-being. For example, ecosystem-based approaches to flood-plain and coastal development can reduce human exposure to risks from flooding. Coral reefs are very effective in protecting against coastal hazards (reducing wave energy by 97%) and protect over 100 million people in this way from coastal storm surges. The conservation and use of genetic resources in agriculture, aquaculture and forestry is important to allow crops, trees, fish and livestock to adapt to climate change.

SUSTAINABLE CONSUMPTION AND PRODUCTION

66. **Increased pressure on the biosphere, driven by increasing human populations and per-capita consumption, threatens biodiversity and human health.** Biosphere integrity is threatened by a number of interacting drivers, including climate change, land-use change, pollution and biodiversity loss. The global population is projected to increase to nine to ten billion by 2050, and may continue to increase in this century. Greater investment in education of girls and women and improved access to contraceptive information and family-planning services can improve human health and well-being directly and also help to slow these trends, potentially reducing pressures on ecosystems. Under business-as-usual scenarios, increased per-capita consumption will lead to even greater pressures on the biosphere. Slowing these trends requires improvements in energy and resource-use efficiency, including decarbonization of energy supplies in this century. These changes will need to be complemented by increased equality in access to and use of energy and other natural resources.

67. **Alternative scenarios to 2050, as well as practical experience, demonstrate that it is possible to ensure food security and reduce poverty while also protecting biodiversity and addressing climate change, and attain other human development goals, but this requires transformational change.** Scenario analyses show that there are multiple plausible pathways to simultaneously achieve globally agreed goals. Common elements of these pathways include: reducing greenhouse gas emissions from energy and industry; increasing agricultural productivity and containing agricultural expansion to prevent further biodiversity loss and avoid excessive greenhouse gas emissions from conversion of natural habitats; restoring degraded land and protecting critical habitats; managing biodiversity in agricultural landscapes; reducing nutrient and pesticide pollution and water use; reducing post-harvest losses in agriculture, and food waste by retailers and consumers, as well as moderating the increase in meat consumption. Implementing these measures requires a package of actions, including legal and policy frameworks, economic incentives, and public and stakeholder engagement. Coherence of policies and coordination across sectors are essential.

68. **Behavioural change is needed to improve human health and protect biodiversity.** Human behaviour, which is informed by differences in knowledge, values, social norms, power relationships and practices, is at the core of the interlinkages between health and biodiversity, including challenges related to food, water, disease, medicine, physical and mental well-being, adaptation and mitigation of climate change. There is a need to draw upon the social sciences to motivate choices consistent with health and biodiversity objectives, and to develop new approaches through, inter alia, better understanding of behavioural change, production and consumption patterns, policy development, and the use of non-market tools. There is a need for more effective communication, education and public awareness to be spread more widely through school systems and other channels, and to devise communication and awareness strategies on biodiversity and health.

STRATEGIES FOR HEALTH AND BIODIVERSITY

69. **Health and biodiversity strategies could be developed with the aim of ensuring that the biodiversity and health linkages are widely recognized, valued, and reflected in national public health and biodiversity strategies, and in the programmes, plans, and strategies of other relevant sectors, with the involvement of local communities.** The implementation of such strategies could be a joint responsibility of ministries of health, environment, and other relevant ministries responsible for the implementation of environmental health programmes and national biodiversity strategies and action plans. Such strategies would need to be tailored to the needs and priorities of particular countries. Such strategies might include the following objectives:

a) Promoting the health benefits provided by biodiversity for food security and nutrition, water supply and other ecosystem services, pharmaceuticals and traditional medicines, mental health, and physical and cultural well-being. In turn, this provides a rationale for the conservation and sustainable use of biodiversity, as well as the fair and equitable sharing of benefits;

b) Managing ecosystems to reduce the risks of infectious diseases, including zoonotic and vector-borne diseases, for example, by avoiding ecosystem degradation, preventing invasive alien species, and limiting or controlling human–wildlife contact;

c) Addressing the drivers of environmental change (deforestation and other ecosystem loss, and degradation and chemical pollution) that harm both biodiversity and human health, including direct health impacts and those mediated by biodiversity loss;

d) Promoting lifestyles that might contribute jointly to positive health and biodiversity outcomes (for example, protecting traditional foods and food cultures, promoting dietary diversity);

e) Addressing the unintended negative impacts of health interventions on biodiversity (for example, antibiotic resistance, contamination from pharmaceuticals), and incorporating ecosystem concerns into public health policies;

f) Addressing the unintended negative impacts of biodiversity interventions on health (for example, effect of protected areas or hunting bans on access to food and medicinal plants);

g) Adopting the One Health approach or other integrative approaches that consider connections between human, animal and plant diseases, and promote cross-disciplinary synergies for health and biodiversity;

h) Educating, engaging and mobilizing the public and the health sector, including professional health associations as potential, powerful advocates for the sustainable management of ecosystems. Mobilize organizations and individuals who can articulate the linkage and the enormous value proposition that investments in sustainable ecosystem management provide to the social and economic health of communities;

i) Monitoring, evaluating and forecasting progress toward the achievement of national, regional and global targets at regular intervals against evidence-based indicators, including threshold values for critical ecosystem services, such as the availability and access to food, water and medicines.

TOOLS, METRICS AND FURTHER RESEARCH

70. **Integration of biodiversity and human health concerns will require the use of common metrics and frameworks.** Conventional measures of health are often too limited in focus to adequately encompass the health benefits of biodiversity. Notwithstanding the broad WHO definition of health, traditional measures of health, such as disability-adjusted life years (DALYs) and burden of disease, tend to have a narrower focus on morbidity, mortality and disability, and fail to capture the full breadth of complex linkages between biodiversity and health. Alternative metrics defining health are needed to reflect the broad aspects of human health and well-being. Further, to increase collaboration across disciplines and sectors, more attention could be paid to "translating" the meaning of key metrics to increase shared relevance. Similarly, frameworks provide a conceptual structure to build on for research, demonstration projects, policy and other purposes. Embracing a broad framework that aims to maximize the health of both ecosystems and humans could help the different disciplines and sectors work more collaboratively. The conceptual framework of the Intergovernmental science-policy Platform on Biodiversity and Ecosystem Services (IPBES), building upon that articulated in the Millennium Ecosystem Assessment, links biodiversity to human well-being, considering also institutions and drivers of change.

71. **The development of comparable tools – and maximizing the use of existing tools – to promote a common evidence base across sectors is needed.** Tools ranging from systematic assessment processes (for example, environmental impact assessments, strategic environmental assessments, risk assessments and health impact assessments) to the systematic reviews of research findings, to standardized data collection forms to computerized modelling programs should also consider health–biodiversity linkages to manage future risks and safeguard ecosystem functioning, while ensuring that social costs, including health impacts, associated with new measures and strategies do not outweigh potential benefits.

72. **The development of precautionary policies that place a value on ecosystem services to health, and make positive use of linkages between biodiversity and health are needed.** For example, integrated disease surveillance in wildlife, livestock and human populations is a cost–effective measure to promote early detection, and avoid the much greater damage and costs of disease outbreaks.

73. **Measuring the health effects of ecosystem change by considering established "exposure" threshold values helps highlight biodiversity–health–development linkages.** Mechanisms linking ecosystem change to health effects are varied. For many sub-fields, exposure thresholds or standards have been scientifically established, which serve as trigger points for taking action to avoid or minimize disease or disability. For example, air quality standards exist for particle pollution, WHO has established minimum quantities of per-capita water required to meet basic needs, and thresholds for food security define the quantity of food required to meet individual daily nutritional needs. Measuring the health effects of ecosystem change relative to established threshold values highlights how such change constitutes exposure – an important principle linking cause and disease or other health effects – and encourages action if thresholds are exceeded.

74. **Economic valuation approaches linking ecosystem functioning and health, which support decisions about resource allocation, may appeal to a variety of stakeholders.** Many approaches enhance understanding of ecosystem functioning and human health linkages. Common on the health side are environmental hazard or risk factor analyses. Others include identifying and reducing health disparities/inequities; focusing on environmental and socioeconomic determinants of disease, and conducting health impact assessments. Conservation approaches include land-/seascape-change modelling, vulnerability and adaptation assessments, linked health and environmental assessments, and ecosystem service analyses.

75. **Further research is needed to elucidate some of the potential knowledge gaps in linkages between biodiversity and human health.** Examples of key questions include the following:

a) What are the relationships between biodiversity, biodiversity change and infectious diseases? Specifically, what are the effects of species diversity, habitat disturbance and human–wildlife contact? What are the implications for spatial planning?

b) What are the linkages between biodiversity (including biodiversity in the food production system), dietary diversity and health? Is there a relationship between dietary biodiversity and the composition and diversity of the human microbiome? What are good indicators of dietary biodiversity? What are the cumulative health impacts of ecosystem alteration?

THE SUSTAINABLE DEVELOPMENT GOALS AND POST-2015 SUSTAINABLE DEVELOPMENT AGENDA

76. **Health and biodiversity, and the linkages among them and with other elements of sustainable development, must be well integrated into the post-2015 development agenda.** The post-2015 development agenda provides a unique opportunity to advance the parallel goals of improving human health and protecting biodiversity. The Sustainable Development Goals (SDGs) will address various aspects of human well-being and be accompanied by targets and indicators. Specific biodiversity-related targets and indicators should be integrated into Goals on food security and nutrition, water and health. The SDG framework should also provide for enabling conditions for human health, and conservation and sustainable use of biodiversity, and for the underlying drivers of both biodiversity loss and ill-health to be addressed. This implies Goals for improved governance, and institutions, at appropriate scales (from local to global), for the management of risks and the negotiation of trade-offs among stakeholder groups, where they exist, as well as for behavioural change.

77. **Ongoing evaluation of the synergistic and antagonistic effects of complementary sustainable development goals and targets is needed.** This includes sustainable development goals and targets addressing health, food and freshwater security, climate change and biodiversity loss. Evaluation of the long-term impacts of trade-offs is needed; such as the trade-off and short-term gains from intensive and unsustainable agricultural production against longer-term nutritional security. For example, the impacts of

unsustainable agricultural practices that may exacerbate climatic pressures may also lead to greater food insecurity, particularly among poor and vulnerable populations, by negatively influencing its availability, accessibility, utilization and sustainability.

78. **Health is our most basic human right and therefore one of the most important indicators of sustainable development.** At the same time, conservation and sustainable use of biodiversity is imperative for the continued functioning of ecosystems at all scales, and for the delivery of ecosystem services that are essential for human health. There are many opportunities for synergistic approaches that promote both biodiversity conservation and the health of humans. However, in some cases, there must be trade-offs among these objectives. Indeed, because of the complexity of interactions among the components of biodiversity at various tropical levels (including parasites and symbionts), and across ecosystems at various scales (from the planetary-scale biomes to human– microbial interactions), positive, negative and neutral links are likely to occur simultaneously. An enhanced understanding of health–biodiversity relationships will allow for the adjustment of interventions in both sectors, with a view to promoting human well-being over the long term.

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