INFECTIOUS DISEASES

Ecology, drivers, climate breakdown & the need for nature action

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SOME KEY FACTS WITH POLICY RECOMMENDATIONS FOR THE WORLD HEALTH ORGANIZATION 'ONE HEALTH INITIATIVE'

The current COVID-19 pandemic crisis has put the spotlight on some critical issues of the destruction of nature including the use of wildlife, which seriously threaten human health at the global level. Calls have been raised for (i) global ban on wild animal markets[1], (ii) global ban on international trade of live wildlife (not intended for conservation purposes)[2], (iii) protecting wildlife habitats[3], (iv) reducing the exposure of wildlife and people by overhauling the current approaches to urban planning and development[4], and (v) the overhaul of food habits, with drastically changing of our diets and moving to plant-rich foods[5]. From the different options proposed, it is clear that the issues relating to transformation of nature and the commercialization of wildlife are of particular importance.

This paper provides a rapid overview of the relationship between nature, wildlife, human food habits, climate change and infectious disease pandemics with a set of ***policy recommendations*** on how to reduce the risks of infectious diseases in the future related to the management of nature, including wildlife use and consumption.

1 SHORT BACKGROUND

HUMAN TRANSFORMATION OF NATURE IS THE PRIME DRIVER OF INFECTIOUS DISEASES

The transformation of nature, and especially of primary ecosystems, has increased the exposure of humans to pathogens originating in wildlife. Together with the industrialization of food production both on land and in sea and the conversion of land for farming and extractive industries, conversion has accounted for almost half of all global zoonotic infectious diseases. The fragmentation of natural landscapes, with less top predators, further increases the risks. Commercialization of wildlife as human food has contributed to several significant zoonotic

1 https://www.theguardian.com/world/2020/apr/06/ban-live-animal-markets-pandemics-un-biodiversity-chief-age-of-extinction
2 E.g. Letter on April 8, 2020, by Congress of the United States to WHO, OIE and FAO on the issues live wildlife markets and trade of live wildlife, https://news.mongabay.com/2020/03/conservationists-set-the-record-straight-on-covid-19s-wildlife-links/
3 E.g. https://time.com/5817363/wildlife-habitats-disease-pandemics/
4 https://www.iied.org/coronavirus-threat-looms-large-for-low-income-cities
5 https://www.theguardian.com/science/2020/jun/03/jane-goodall-humanity-is-finished-if-it-fails-to-adapt-after-covid-19?CMP=share_btn_link

infectious disease transmissions to humans. Biodiversity hotspots in tropical regions, with higher number of mammal species and larger pool of pathogens, might contribute more to the disease emergence risk.

SPILLOVER OF ZOONOTIC VIRUSES HIGHEST IN MAMMALS, WITH LARGEST RISKS IN DOMESTICATED SPECIES

Rodents, bats and primates account for more than 70% of all reported zoonotic viruses. As a group, domesticated mammals host 50% of the zoonotic viruses but represent only 12 species, with up to eight times more viruses per species compared to wild mammal species. More abundant, common mammal species with increasing populations have significantly more zoonotic viruses compared to species with stable or declining population trends. Wildlife species threatened from over exploitation through hunting and wildlife trade have twice as many zoonotic viruses as those species endangered for other reasons. The alteration of natural areas from forest fragmentation, development and conversion to croplands and other human activities increases the probability of animal-human interactions, and hence the risk for virus spillover.

WILD MEAT HARVESTING AND CONSUMPTION & WILD ANIMAL MARKETS INCREASE SIGNIFICANTLY THE RISKS FOR INFECTIOUS DISEASE SPILLOVER

Wild meat harvesting and consumption of many species increases significantly the risks for infectious disease spillover. Terrestrial animals, freshwater and marine fish, and in some situations invertebrates, are important protein sources, and contribute to the food security of millions of people across the world. More recently, growing human populations, logging and mining operations, technological elaborations, weak governance/corruption, increasing urban demands and the emergence of a booming commercial wild meat trade have culminated in unprecedented harvest rates that cause the decline of numerous wildlife populations, endangered high-profile species, and the “empty forest syndrome”. To secure a sustainable meat basis, in particular for marginalized communities, tools such as community-based wildlife management at a landscape level (e.g. community conservancies), wildlife ranching, certification, and provisions of alternative livelihoods have been implemented. To reduce the risks linked to bushmeat in Africa, it has been proposed to restrict hunting of primates, and invest in culturally appropriate education, better disease surveillance and research.

"Wet markets" have been identified as especially high risk of transmitting zoonoses. However, the "animal underworld" of wild exotic *pet* species are found in most countries, and they are exposed to the same problems as wet markets with high mortalities of animals, stress, risks of animal/human transfer of diseases, etc.

WILDLIFE TRADE IS A CONSIDERABLE RISK FACTOR

The multibillion-dollar industry of wildlife trade affects negatively almost one in five species of birds, mammals, amphibians and reptiles globally. This not only endangers the survival of thousands of species but also threatens the overall function of ecosystems, leading to "ecological extinction" with serious consequences for mitigating climate change and other ecosystem services. The overlap between the origin of most species in trade and the areas with the highest level of Emerging Infectious Diseases (EIDs), is a considerable risk factor when it comes to combating infectious diseases worldwide.

CLIMATE CHANGE – AN ADDITIONAL RISK FACTOR

Projections as well as recent developments have demonstrated that climate change will have a significant impact on the expansion of infectious diseases, including their host species reservoirs.

2 POLICY RECOMMENDATIONS

OVERALL

Rather than sustainable use of wildlife per se, our goal should be "ecological sustainability" – defined as policies and actions that protect and strengthen nature's ability to provide abundant, life-supporting ecosystem services, such as following scientific guidelines to protect at least half the Earth's land and seas, and others. By doing this we seek to end "exploitation without ethics" and foster a new relationship between humankind and nature, thereby vastly reducing human encroachment on wild areas, abusive use of wildlife and domestic animals, and dangerously unhealthy commercialization of wildlife.

IN ADDITION, WE SHOULD:

- Adopt the WHO "One Health"[6] ecological approach rather than a simplistic "one germ, one disease" approach, conserving the critical links between humans, animals (domestic

6 https://www.who.int/features/qa/one-health/en/ 7 https://drive.google.com/file/d/10QXhnzX4HQyJWZuYZ09URvosA4QU0Kph/view

& wild) and the environment, creating a more successful outcome for the future.

- The "One Health" initiative should specifically include the following components:
  - » ***Protect & Restore:*** Immediately stop the destruction of all primary ecosystems on the Planet combined with a large-scale restoration of ecosystems;
  - » ***Rewild:*** Rebuild the ecological functions of ecosystems by applying the principles of rewilding as outlined in the Global Charter for Rewilding the Earth[7], which would reduce the spread of zoonotic diseases;
  - » ***Ban Wildlife Trade:*** To reduce the risks of infectious disease transmission and rebuild the ecological functions of ecosystems, the international trade of live wildlife not intended for conservation purposes should be closed permanently;
  - » ***Change Wildlife Markets:*** To ensure local livelihoods, in particular for marginalized communities, support community-based wildlife management at a landscape level, wildlife ranching, certification and provision of alternative livelihoods. Prohibit the sale/slaughter of wildlife in markets where food for human consumption is distributed or sold. Stop the "animal underworld" of wild exotic pet species markets in all countries.
  - » ***Reduce Climate Emergency:*** Meet the target of 1.50°C rise in average global temperature as agreed in the UNFCCC Paris Agreement to reduce the expansion of infectious diseases, including their host species reservoirs.
  - » ***Adopt A Planetary Health Diet[8] & Move Towards An Agroecological Production System[9]:*** By reducing the meat consumption of domestic animals in favor of plant-based diet would reduce zoonotic viruses transfer from animals to humans as well as reduce the role of domestic animals as intermediate hosts. A reduction of meat consumption worldwide would also significantly reduce the current expansion of livestock farming into primary forests[10].

7 https://drive.google.com/file/d/10QXhnzX4HQyJWZuYZ09URvosA4QU0Kph/view
8 https://www.thelancet.com/commissions/EAT
9 http://files.panap.net/resources/Agroecology-PAN-International-Position-Paper-en.pdf
10 https://science.sciencemag.org/content/360/6392/987

APPENDIX BACKGROUND INFORMATION

1 SUSTAINABLE USE OF NATURAL RESOURCES, ESPECIALLY WILDLIFE

The sustainable use of wildlife can be either consumptive or non-consumptive, lethal or non-lethal[11]. It can be carried out for commercial, recreational or subsistence purposes by individuals, businesses or governments. In a widest sense, it includes animals, plants and fungi. Sustainable use of wildlife "underpins many local and national economies and supports the livelihoods and cultures of millions if not billions of people".

The issue of sustainable use of nature is at the core of the Convention on Biological Diversity (CBD), as expressed in the foundation text (preamble, objective, Article 2 & Article 10)[12]. The Convention on International Trade in Endangered Species of Wild Fauna and Flora[13] (CITES), is founded on the recognition "that international co-operation is essential for the protection of certain species of wild fauna and flora against over-exploitation through international trade", although it does not explicitly refer to the principle of sustainable use. While the CBD explicitly refers to the issue of health and infectious diseases[14], CITES explicitly states that "matters regarding zoonotic diseases are outside of CITES's mandate[15]."

2 INFECTIOUS DISEASES & TRANSFORMATION OF NATURE

(Main source: https://www.cbd.int/health/SOK-biodiversity-en.pdf)

The transformation of nature, and especially of primary ecosystems, have increased the exposure of humans to pathogens originating in wildlife. Together with the industrialization of food production both on land and in sea and the conversion of land for farming and extractive industries have accounted for almost half of all global zoonotic infectious diseases. The fragmentation of natural landscapes, with less top predators, further increases the risks. Wildlife trade has contributed to several significant zoonotic infectious disease transmissions to humans. Biodiversity hotspots in tropical regions, with higher number of mammal species and larger pool of pathogens, might contribute more to the disease emergence risk.

11 https://www.iied.org/despite-covid-19-using-wild-species-may-still-be-best-way-save-them
12 https://www.cbd.int/convention/text/
13 https://www.cites.org/eng/disc/text.php
14 https://www.cbd.int/health/SOK-biodiversity-en.pdf
15 https://www.cites.org/eng/CITES_Secretariat_statement_in_relation_to_COVID19

Here are some key facts:

- The trend of Emerging Infectious Diseases (EIDs) is accelerating with over 300 distinct events recorded in the last six decades and 35 new infectious diseases since 1980[16].
- Two-thirds of known infectious pathogens have emerged from animals, with the majority of recently emerging pathogens originating in wildlife.
- The most devastating pandemics in human history, the Black Death, Spanish influenza and HIV/AIDS, were all caused by zoonoses from wildlife.
- Anthropogenic disturbance and biodiversity loss have been strongly linked to increased prevalence and elevated risk of zoonotic diseases.
- Human-induced land use changes are primary drivers of range of infectious disease outbreaks (Figure 1), with more than half of the studies demonstrating increased pathogen transmission.
- Together with food production and agricultural change, land use change collectively account for almost half of all global zoonotic emergent infectious diseases (see Figure 1).
- In tropical areas where primary forests are opened up to extractive industries (mining, logging, plantations, oil and gas extraction), such developments have been associated with outbreaks of Marburg virus, Chagas disease, yellow fever, and others.
- Following are examples of how biodiversity loss increases the risk for zoonotic diseases: (i) mammal diversity decrease & hantavirus, (ii) decrease in non-passerine bird richness & West Nile virus, (iii) removal of large wildlife species & Bartonella bacteria, (iv) habitat fragmentation & Lyme disease.
- Changing species composition, such as the loss of top predators, in small fragments of more original habitats remaining in south eastern Brazil (Atlantic Forests) and Eastern United States (temperate forests) have increased zoonotic diseases.
- Deforestation has coincided with an upsurge of malaria in Africa, Asia and Latin America, often associated more areas of still water necessary for breeding of malaria-transmitting mosquitoes (e.g. paddy-field rice cultivation). In regions with large

16 https://www.nature.com/articles/nature06536

hydropower plants in the Amazon, the rate of malaria is more than 250 times higher than in forested areas.

- Deforestation in Africa increases the direct/indirect contacts between humans and the natural reservoirs, such as yellow fever.
- Genetic erosion may occur with decreasing species populations, resulting in selection of receptive individuals for new pathogens or ones without ability to adapt to growing resistance to pathogens already present.
- The reduction of fish stocks and the declining size of fish caught in marine systems may be a risk factor for parasitic worm (helminth) transmission.
- The intensification of livestock production (high animal density, confined living quarters & antimicrobial use) in many parts of the world has created conditions that may enable rapid pathogen to spread and evolve.
- Livestock may serve as intermediate hosts for zoonotic disease transmission from wildlife to humans (e.g. Nipah virus in fruit bats-pigs-humans).
- Wildlife trade has contributed to several significant zoonotic infectious disease transmissions to humans (e.g. SARS, HIV, monkeypox virus, and H7N9 avian influenza viruses).
- Biodiversity hotspots, with larger pool of pathogens, might contribute more to the disease emergence risk but with variations between taxa.
- EID risk is elevated in forested tropical regions experiencing land-use changes and where wildlife biodiversity (mammal species richness) is high[17] (Figure 2).

17 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5654761/pdf/41467_2017_Article_923.pdf

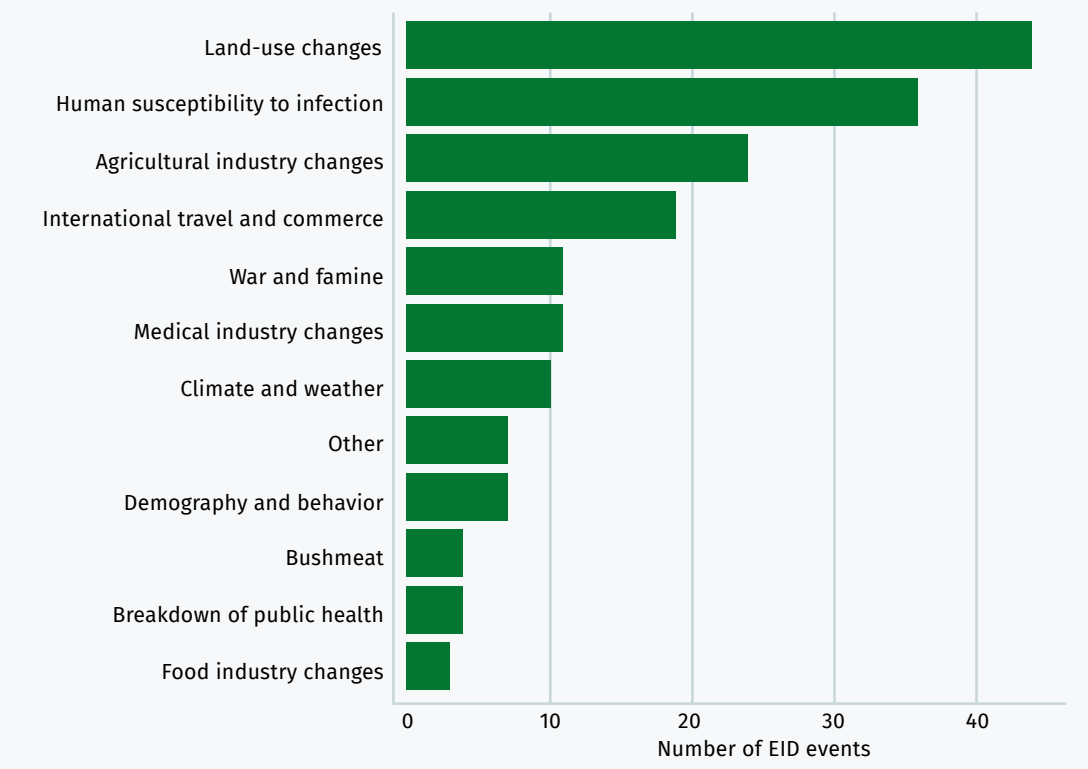

Figure 1: Drivers of emerging infectious diseases from wildlife (Loh et al., Vector Borne and Zoonotic Diseases. In press)

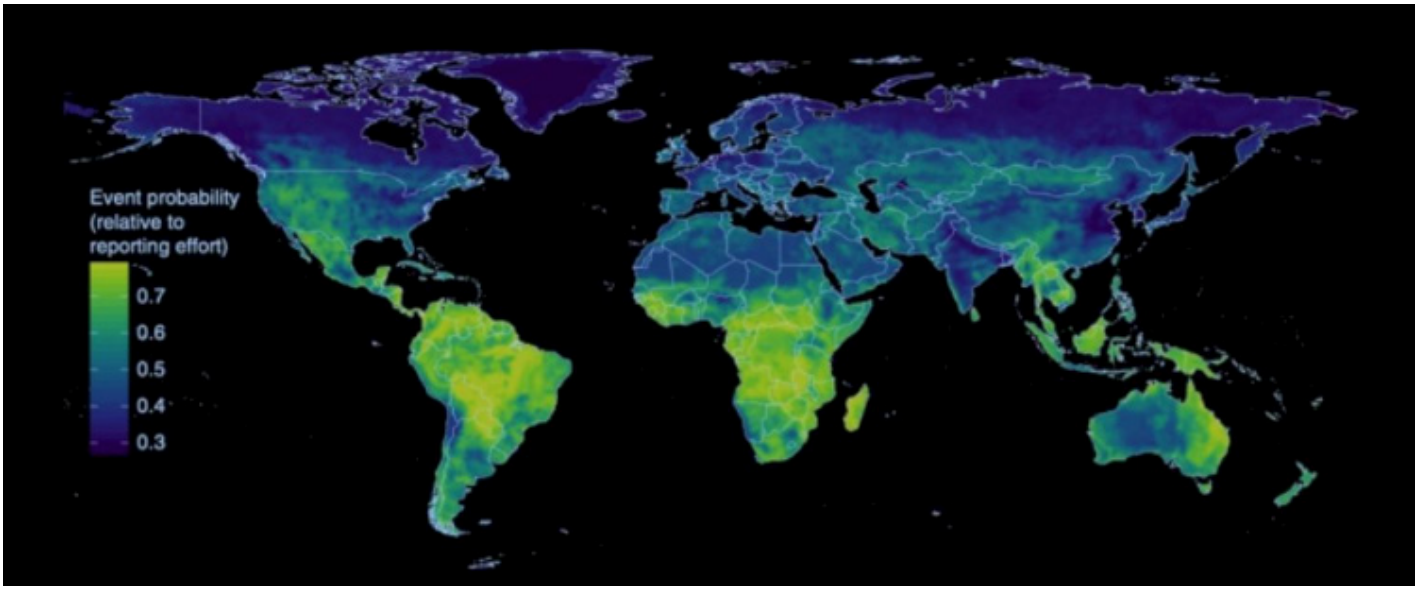

Figure 2: Emerging Infectious Diseases (EID) risk index map showing the relationship to land-use changes in forested tropical regions and where wildlife (mammal) is particularly high.

3 VIRUS SPILLOVER RISKS IN MAMMALS

(Main source: https://royalsocietypublishing.org/doi/10.1098/rspb.2019.2736)

Rodents, bats and primates account for more than 70% of all reported zoonotic viruses. As a group, domesticated mammals host 50% of the zoonotic viruses but represent only 12 species, with up to eight times more viruses per species compared to wild mammal species. More abundant, common mammal species with increasing populations have significantly more zoonotic viruses compared to species with stable or declining population trends. Wildlife species threatened from over exploitation through hunting and wildlife trade have twice as many zoonotic viruses as those species endangered for other reasons. The alteration of natural areas from forest fragmentation, development and conversion to croplands and other human activities increases the probability of animal-human interactions, and hence the risk for virus spillover.

Here are some key facts:

- Domestication of animals, human encroachment into habitats high in wildlife biodiversity and hunting of wild animals have been proposed as key human activities driving infectious disease emergence at the global scale.
- Among 5,335 wild terrestrial mammal species, only 609 (or 11.4%) have been identified with one or more of the zoonotic viruses, with most of them (354) hosting only one zoonotic virus each.
- The groups with the highest proportion of viruses are rodents (61%), bats (30%), primates (23%), even-toed ungulates (e.g. camels), and carnivores (18%). Mammal orders with more species are the source of more zoonotic viruses. Rodents, bats and primates account for 73% of all land-based mammals.
- As a group, domesticated mammals host 50% of the zoonotic viruses but represent only 12 species, with up to eight times more viruses per species compared to wild mammal species. Those domestic species with highest global numbers also hosts the majority of viruses.
- Les common wildlife species shares fewer viruses with humans, whilst more abundant, common mammal species with increasing populations have significantly more zoonotic viruses compared to species with stable population trends.

- Wildlife species threatened from over exploitation through hunting and wildlife trade have twice as many zoonotic viruses as those species endangered for other reasons.
- The alteration of natural areas from forest fragmentation, development and conversion to croplands and other human activities increases the probability of animal-human interactions, and hence the risk for virus spillover.
- Direct and indirect contacts with wildlife in management and ecotourism settings is a recognized risk for zoonotic spillover.

4 WILD MEAT/BUSHMEAT, WILD ANIMAL MARKETS, AND INFECTIOUS DISEASES

Wild meat (bushmeat) in the form of terrestrial animals, freshwater and marine fish, and in some situations invertebrates, are important protein sources, and contribute to the food security of millions of people across the world[18]. More recently, growing human populations, logging and mining operations, technological elaborations, weak governance/corruption, increasing urban demands and the emergence of a booming commercial wild meat trade have culminated in unprecedented harvest rates that cause the decline of numerous wildlife populations, endangered high-profile species, and the "empty forest syndrome". To secure a sustainable meat basis, in particular for marginalized communities, tools such as community-based wildlife management at a landscape level (e.g. community conservancies), wildlife ranching, certification, and provisions of alternative livelihoods have been implemented. Wild meat harvesting and consumption of many species increases significantly the risks for infectious disease spillover. To reduce the risks linked to bushmeat in Africa, it has been proposed to restrict hunting of primates, and invest in culturally appropriate education, better disease surveillance and research[19].

Wild animal markets in different forms occur in most countries. The, so called, wet markets occur mainly in south-east Asia including the following countries: China (incl. Hong Kong), Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Taiwan, Thailand, and Vietnam[20], but also in Mexico. Wet markets have been identified as especially high risk of transmitting zoonoses. However, the "animal underworld" of wild exotic pet species are found in most countries[21], and they are exposed to the same problems as wet markets with high mortalities, risks of transfer of diseases, etc.

18 https://www.cbd.int/sbstta/sbstta-21-wg8j-10/CIFOR-CBD-wildmeat-info-doc-review-en.pdf
19 https://www.researchgate.net/publication/289522055_Bushmeat_and_Emerging_Infectious_Diseases_Lessons_from_Africa
20 https://en.wikipedia.org/wiki/Wet_market
21 https://www.peta.org/issues/animal-companion-issues/animal-companion-factsheets/inside-exotic-animal-trade/

Here are some additional key facts:

- Wild meat consumption includes a wide range of animals such as invertebrates, amphibians, reptiles, birds and mammals. Massive overhunting of wildlife for meat occurs across the humid tropics (Africa, Asia and Latin America) and is causing local extinctions of numerous species[22].
- Wild meat consumption in West/Central Africa is often referred to as "bushmeat".
- Human wild meat/bushmeat activities have been linked to numerous virulent disease outbreaks, such as Ebola, HIV and monkeypox.
- Pathogen spillover from wild meat/bushmeat can occur through consumption, but the main risks are associated with exposure to body fluids and feces during handling and butchering.
- Drivers for the increased bushmeat hunting are the rapid human population growth and urban consumption, facilitated by logging operations including new roads and improved transportation. International markets for bushmeat is also rapidly developing, linked to wildlife trade.
- Zoonotic pathogens with strong evidence for spillover to humans have been documented in many mammal bushmeat species in Africa: 38 primates, 14 bats, 10 rodents, and 13 ungulates.

5 THE IMPACTS OF WILDLIFE TRADE

(Main source: https://science.sciencemag.org/content/366/6461/71)

The multibillion-dollar industry of wildlife trade affects negatively almost one in five species of birds, mammals, amphibians and reptiles globally. This not only endangers the survival of thousands of species but also threatens the overall function of ecosystems, leading to "ecological extinction" with serious consequences for mitigating climate change and other ecosystem services. The overlap between the origin of most species in trade and the areas with the highest level of Emerging Infectious Diseases (EIDs), is a considerable risk factor when it comes to combating infectious diseases worldwide.

22 https://www.sciencedirect.com/science/article/abs/pii/S016953470300123X

Here are some additional key facts:

- Wildlife trade is a multibillion-dollar industry that is driving species towards extinction.
- Of more 31,500 terrestrial species of birds, mammals, amphibians and reptiles, around 18% are traded globally.
- Most of the species in trade originate in the biologically diverse tropics, which overlaps with areas with the highest level of Emerging Infectious Diseases (EIDs) risks.
- In the future, an additional 3'196 species could be affected.
- With exception of habitat loss, wildlife trade has caused more species extinctions than any other factor.
- Wildlife trade also places substantial pressure on biodiversity through the introduction of pathogens, like the lethal amphibian fungus *Batrachochytrium dendrobatidis* eradicating amphibians across the world.
- Trade follows a rarity-value feedback model, whereby increasing rarity drives both higher demand as well as higher prices for a species.
- In many areas, harvesting of wildlife represents one of few opportunities for cash income.
- However, the loss of ecological interactions may occur long before species disappearance, affecting species functionality and ecosystem services at a faster rate than species extinctions, leading to "ecological extinction"[23].
- Consequently, wildlife trade could play a critical role in the ecological extinction of species, with potential, negative consequences for overall health of ecosystems, the wellbeing of other species, and critical ecosystem traits, such as carbon mitigation – and, hence, climate change.
- Significant zoonotic infectious diseases have emerged due to the substantial human-animal contact that occurs along the wildlife trade chain, from harvest to end point[24].

23 https://besjournals.onlinelibrary.wiley.com/doi/10.1111/1365-2435.12356
24 https://www.cbd.int/health/SOK-biodiversity-en.pdf
25 https://www.cbd.int/health/SOK-biodiversity-en.pdf

- The global trade in wildlife provides disease transmission mechanisms that not only result in human and animal health threats but also damages to international trade, agricultural livelihoods, and global security[25].

6 CLIMATE CHANGE AND INFECTIOUS DISEASES

(Main sources: https://www.cbd.int/health/SOK-biodiversity-en.pdf, https://www.who.int/globalchange/181008_the_1_5_healthreport.pdf)

Projections as well as recent developments have demonstrated that climate change will have a significant impact on the expansion of infectious diseases, including their host species reservoirs.

Here are some additional key facts:

- Climate change affects the distribution and risk of many infectious diseases.
- The impacts of climate change and associated shifts in species range as well as the pathogens for which they may serve as a host or reservoir.
- For example, the habitat range and distribution of the bat reservoir for the Nipah virus will increase significantly due to climate change, and hence increase the human disease risk.
- These risks may be compounded by increasing movement of species through trade and travel and the evolution of more suitable habitats for invasive alien species.
- Through climate change, diseases like malaria, dengue fever and Vibrio species (e.g. cholera) is projected to increase geographically[26].
- A relationship between infectious diseases outbreaks and climate change events, like El Nino, heatwaves, droughts and floods, have been demonstrated[27].

26 https://www.thelancet.com/action/showPdf?pii=S0140-6736%2819%2932596-6
27 https://www.researchgate.net/publication/321648604_The_Impact_of_Global_Environmental_Changes_on_Infectious_Disease_Emergence_with_a_Focus_on_Risks_for_Brazil