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Freshwater management, emerging infectious diseases, and human health

The COVID-19 pandemic has spurred governments and funders to identify measures that can reduce risk of future emerging infectious diseases (EID) affecting human health and well-being. Among these, the conservation of natural ecosystems, including more sustainable management of forests, agriculture, and wildlife, have a strong and credible potential to reduce risk of future EID events. Here I focus on some aspects of the management of freshwater resources and ecosystems that are relevant for reducing the risk of future EID events and pandemics.

While COVID-19 is an emerging disease that recently spilt over from animals to humans (an 'emerging infectious zoonotic disease') endemic (long-established) zoonotic diseases, such as malaria and dengue fever impose a greater overall health burden on people globally, particularly in the Global South. Further, infectious diseases that are not zoonotic, including waterborne diseases, are among the leading causes of mortality worldwide; beyond disease, a range of toxins and pollutants in water also impose significant global health burdens.

Thus, our policies and interventions for responding to the current pandemic, and development of strategies that link conservation and human health, should not be limited to only COVID-19 or zoonotic diseases, but should address the broader nexus of ecosystems, agriculture and human health.

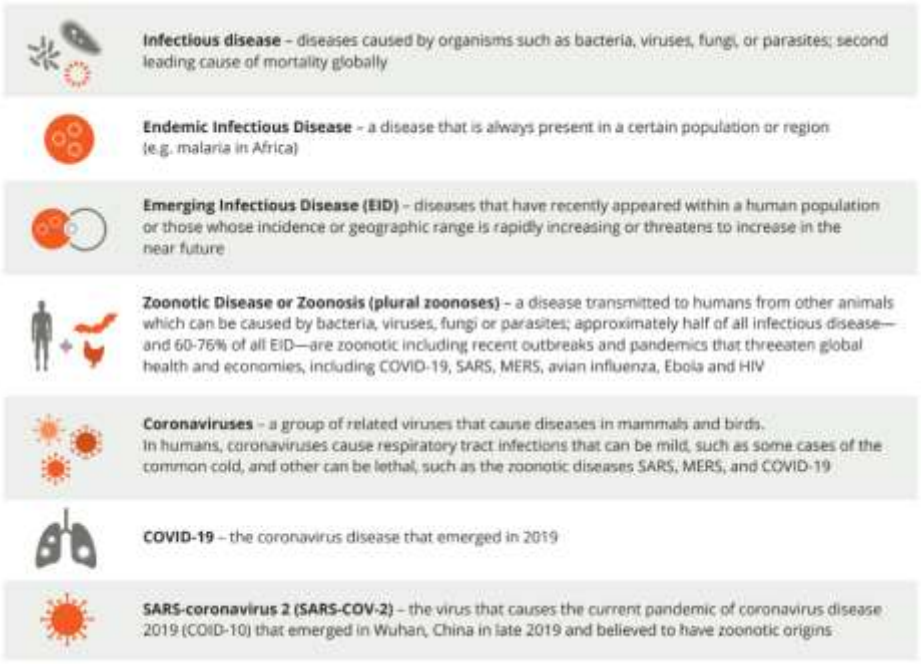
In addition to a discussion of EID, we'll conclude with a brief review of the global health implications of endemic diseases, including waterborne diseases, and potential freshwater-focused interventions that can address risk from EID, endemic disease, or both.

Current focus on pandemics from Emerging Infectious Disease and connection with freshwater issues

The risk of a new zoonotic EID event (i.e., the spill over of a novel virus) is a function of exposure and vulnerability. *Exposure* is the likelihood of contact with a pathogen, while *vulnerability* is the likelihood that a given exposure to a pathogen will cause harm. Thus, reducing risk requires reducing exposure, reducing vulnerability, or both and therefore requires an understanding of the drivers of exposure and

vulnerability. In the review of the literature in "Beyond Boundaries" science brief (WWF 2020), we identified the following primary direct drivers of exposure:

1. Land-use change and expansion of agriculture
2. Exploitation of wildlife
3. Intensification of agriculture, particularly domestic livestock production.



The science brief also focuses on indirect drivers that influence these direct drivers, including governance, food consumption and diets, and climate change (note that climate change can also be considered a direct driver of increased exposure for some diseases). Because water management exerts a strong role on land-use change and agriculture, we could consider water management to be another indirect driver (and, as discussed below, water management may be a direct driver for some diseases).

Understanding the drivers of disease emergence can allow us to identify potential leverage points for interventions. But to do this, it's important to remember that of course not all diseases are the same. The relevant drivers will vary depending on the dynamics of the disease – including the species of host and how the disease transmits. Table 1 below categorizes various types of zoonotic pathogens and transmission pathways and the drivers associated with those pathways—giving insight to the interventions relevant to influence specific drivers and disease transmission pathways (the final column, "linkage with freshwater" was added for this document).

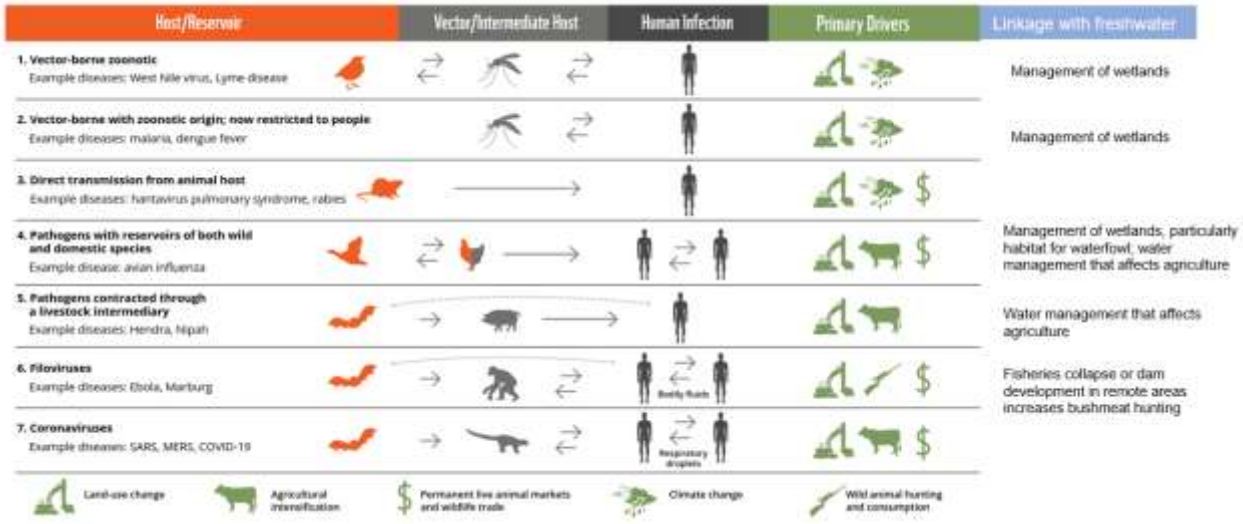
Next, we review the *freshwater-related drivers* related to both exposure and vulnerability.

<u>Exposure</u>

1. *Infrastructure development, including hydropower, in remote regions can increase risk of exposure to zoonotic EIDs.* Infrastructure projects in remote areas, such as hydropower and associated roads, can increase risk of exposure to potential zoonotic pathogens and an EID event in two ways. First, the projects introduce hundreds or even thousands of workers into a remote area, often for years. This can lead to a considerable increase in the hunting of wild meat (either by the workers directly or by people supplying meat to sell to the workers), increasing the risk of exposure (Jones and Bull 2020). Second, the roads and other infrastructure can facilitate people entering or moving into those areas over the long run, increasing hunting and other forms of contact with wildlife.

- *Potential intervention:* Hydropower projects could be required to perform Health Impact Assessments (Osofsky and Pongsiri 2018), or to fully incorporate assessment of health risks into the planning and review process for hydropower projects.

Table 1. Types of pathogens and transmission pathways for zoonotic infectious diseases and their drivers (adapted from WWF 2020; column "linkage with freshwater" was added for this document).



2. *The status of fisheries can influence the extent of wild meat hunting and exposure risk.* Communities that engage in fishing may also depend on wild meat for a diversified food portfolio (Teh et al. 2016) and will increase reliance on wild meat when access to fish is limited (Brashares et al. 2004; Mildenstein et al. 2016). Because people will switch protein sources based on availability, a failure to protect access to sustainable and productive freshwater fisheries could lead to increases in wild meat hunting and increased risk of EID outbreaks.
    - *Potential intervention*. Investments to sustainably manage freshwater fisheries (lakes and rivers) could reduce levels of wild meat hunting (Akele et al. 2014). Aquaculture programs could promote alternative sources of protein to reduce pressure on wildlife and risk of EID (Van Vliet 2010) though, in practice, aquaculture programs have had challenges establishing viable alternatives to wild meat hunting in areas where it is important (Evans et al. 2011). Overall, promotion of sustainable fisheries—whether wild capture or aquaculture—can be part of strategies to ensure that policies against wild meat hunting, sale or markets do not negatively impact food security for rural people.

3. *Wetlands and the risk of Avian influenza from wild waterfowl.* Avian influenza is a viral infection of both wild birds, particularly waterfowl, and domestic poultry caused by the Type A strain of the influenza virus. This virus generally doesn't affect humans, but certain strains have transmitted to people through contact with sick or dead poultry, and then sustained person-to-person transmission through a respiratory route. Live bird markets may act as a reservoir of the

virus (World Health Organization 2014). The 1918 flu pandemic may have had an avian origin (Taubenberger & Morens 2019).

Because a common transmission pathway is from wild birds to domestic birds to people, the interaction between wild and domestic birds is a key part of exposure to Avian flu. Wu et al. (2020) found that the proximity of wetlands and rice paddies to poultry farms increased the risk of an Avian flu outbreak. But they also found that proximity of farms to *protected* wetlands decreased the risk of an outbreak. They hypothesized the reduced risk arose because in regions with protected wetlands, those high-quality habitats attracted wild waterfowl and reduced the probability that they would use habitats of unprotected wetlands and rice paddies that are close to farms.

- *Potential interventions*. Protecting wetlands, and effective management of protected wetlands, in regions with poultry farms and risks of Avian flu, could reduce the risk of exposure of domestic birds to the virus from wild waterfowl. Specific management interventions should be explored to reduce risks of exposure of domestic birds to wild birds that use dispersed wetlands and rice paddies in the agricultural landscape.

4. *Water management as a driver of land-use change and agricultural practices.* Two of the most important drivers of EID events are land-use change and expansion or intensification of agriculture (WWF 2020). Water management exerts a strong influence on these two direct drivers and so can be viewed as an important indirect driver of EID events.
    - *Potential interventions*. Strategies for reducing risk of EIDs that are focused on the drivers of land-use change and agricultural practices should consider how water management influences those drivers and use that information to improve design of interventions aimed at affecting those drivers.

<u>Vulnerability</u>

The concept of vulnerability describes the probability of negative outcomes when a human population is exposed to a pathogen. A healthy population will have lower vulnerability, and thus risk of negative outcomes (e.g., less likely for infections to occur and start transmitting) while a population with poor health or nutritional status will have a higher vulnerability and risk of negative outcomes.

A range of issues related to freshwater resources and management are relevant to the vulnerability of populations to EID events, including:

- The vulnerability of a population to an EID event will increase with increasing disease burden of vector-borne diseases (e.g., malaria) and waterborne diseases (e.g., diarrheal diseases). Degradation of water quality can also increase vulnerability, such as negative health outcomes associated with nutrient pollution and toxic metals.

- Water scarcity could increase vulnerability by diminishing the effectiveness or availability of medical care, reducing food availability, dehydration and even simply the lack of access to clean water for hand washing, which is a basic precaution against the spread of EIDs including COVID-19.
- Degradation of freshwater systems could impact food security, and increase vulnerability, by diminishing fishing or agriculture that depends on river flows, nutrients or sediment (Osofksy and Pongsiri 2018).

The One Health concept integrates the risks and drivers of EID with risks and drivers of other threats to human health and explores how management of natural ecosystems affects those relationships.

Freshwater management and endemic infectious diseases

Two diseases with relevance to water management rank in the top seven sources of mortality within low-income countries: diarrheal diseases and malaria.

<u>Diarrheal diseases and water management</u>

- Second leading cause of mortality in low-income countries
- Directly related to the absence of access to clean water and sanitation.
- Even with better human sanitation, fecal contamination from animals and wildlife remains an issue and so intersects with some of the same interactions for EIDs: people-wildlife-livestock and the matrix of natural habitats and livestock.
- Watershed health, as measured by intact forest, can reduce risk of diarrheal disease in children in areas downstream (Herrera et al. 2017).

<u>Vector-borne diseases, water management and climate change</u>

- Climate change can lead to range expansion of vectors of infectious disease that breed in water (e.g., mosquitoes), carrying the disease to new regions and new human populations, as is happening with dengue fever extending northward into the state of Texas (Kilpatrick & Randolph 2012).
- Also, drought related to climate change can cause people to cluster near remaining water sources and if those water sources support the vector then climate change and drought are drivers of increased exposure. Drought led to migration and clustering of people near water sources that supported the vector (phlebotomine sand flies) of leishmaniasis, increasing exposure to the pathogen and incidence of the disease (Thompson et al. 2002 cited in Mills et al. 2010).
- Water-management projects, including dams with reservoirs and irrigation canals, can contribute to increase in incidence of vector-borne diseases such as malaria (Keiser et al 2005).
- Reservoirs can increase risk of schistosomiasis; risk can be influenced by management of wetlands, including by upstream operations of dams (Mafiana et al. 2003).

The way we manage our freshwater resources has implications for sustainable fisheries, agriculture and livelihoods to reduce vulnerability to disease. Protecting our wetlands can reduce the risks of avian

influenza, and protecting and sustainably managing catchments can provide cleaner water for urban areas and reduce the incidence of diarrheal disease. Sustainable water management and allocation can help to avoid droughts that can exacerbate some risks and health burden associated with scarcity. In addition, sustainable ecosystem management can reduce flood risk, which is as a major direct threat to health and also intertwined with disease.

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