PANDEMICS AND PLANETARY HEALTH

Conservation in the COVID-19 aftermath

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Briefing 3: Wildlife, origins of COVID-19, and preventing future pandemics

All expectations were that 2020 would be a 'super year' for conservation – a year of landmark global negotiations to set nature on a pathway to recovery. But instead we got a pandemic. Evidently, it is our destructive relationship with the planet that landed us in this mess. Although COVID-19 is first and foremost a human tragedy, we must also look ahead to how we can mend this broken relationship and push towards a more sustainable and resilient world. From a conservation perspective, this requires an understanding of how our activities jeopardise both planetary and human health so that we may identify leverage points and interventions to help halt both biodiversity loss and future pandemics. This briefing therefore aims to unravel the complex set of anthropogenic and environmental change drivers that amplify zoonotic disease risks. It also highlights how the current pandemic might impact on conservation and our ability to respond to these impinging risks.

> *The message we are getting is if we don't take care of nature, it will take care of us"*
>
> **– Elizabeth Maruma Mrema**
>
> Executive Secretary, UN CBD

While COVID-19 has been described as a 'black swan' – a random and extremely rare event – this pandemic was in fact widely predicted by both academics and national intelligence agencies [1–4]. These predictions partially hinge on the fact that the frequency of novel zoonotic diseases has increased markedly in recent decades, particularly those originating from wildlife [5]. Some of the worst recent human epidemics and pandemics – HIV, Ebola, SARS, MERS and now COVID-19 – have all originated from wild animals (mostly bats) either directly or via a domestic animal intermediary. As early as 2007, scientists cautioned that 'The presence of a large reservoir of SARS-CoV-like viruses in horseshoe bats, together with the culture of eating exotic mammals in southern China, is a time bomb' [1]. Unfortunately, these now-prophetic words were largely ignored at the time of writing and there was little sense of urgency. In 2019, we tragically learned the lessons of over a decade of unheeded warnings when a similar bat-derived virus emerged and proceeded to wreak havoc across the world [6]. Paradoxically, one of the most urgent and extreme responses to the current COVID-19 pandemic has been a call to ban the global wildlife trade in its entirety, given the suspected links between the outbreak and a Chinese market selling wild animals [7]. While the zoonotic risks associated with the wildlife trade are not disputed, such a myopic focus overlooks the many other key drivers of infectious disease emergence – most of which lie with our degradation of the natural world [8,9].

> *That [COVID-19] has occurred at the same time as the planet is undergoing a biodiversity extinction crisis is not a coincidence"*
>
> **– Andrew A. Cunningham**
>
> Zoological Society of London

In the past half century, our planet has experienced unprecedented ecological change, with drastic declines in natural ecosystems and biodiversity, along with similarly drastic increases in humans and domestic animals. By some estimates, ~75% of all terrestrial environments and 66% of marine environments have now been significantly altered by anthropogenic activities [10]. As mankind has incessantly exploited wildlife and their habitats through pursuits such as hunting, agriculture, infrastructure development and extractive industries, we have not only expanded the wildlife–livestock–human interface and modified patterns of species composition and abundance, but we have simultaneously exposed ourselves to a Pandora's box of pathogens and created ideal circumstances for zoonotic spillovers. Despite extensive warnings of global mass extinctions and increasing pandemics, we continue to transgress catastrophic environmental boundaries [11,12] (Fig. 1).

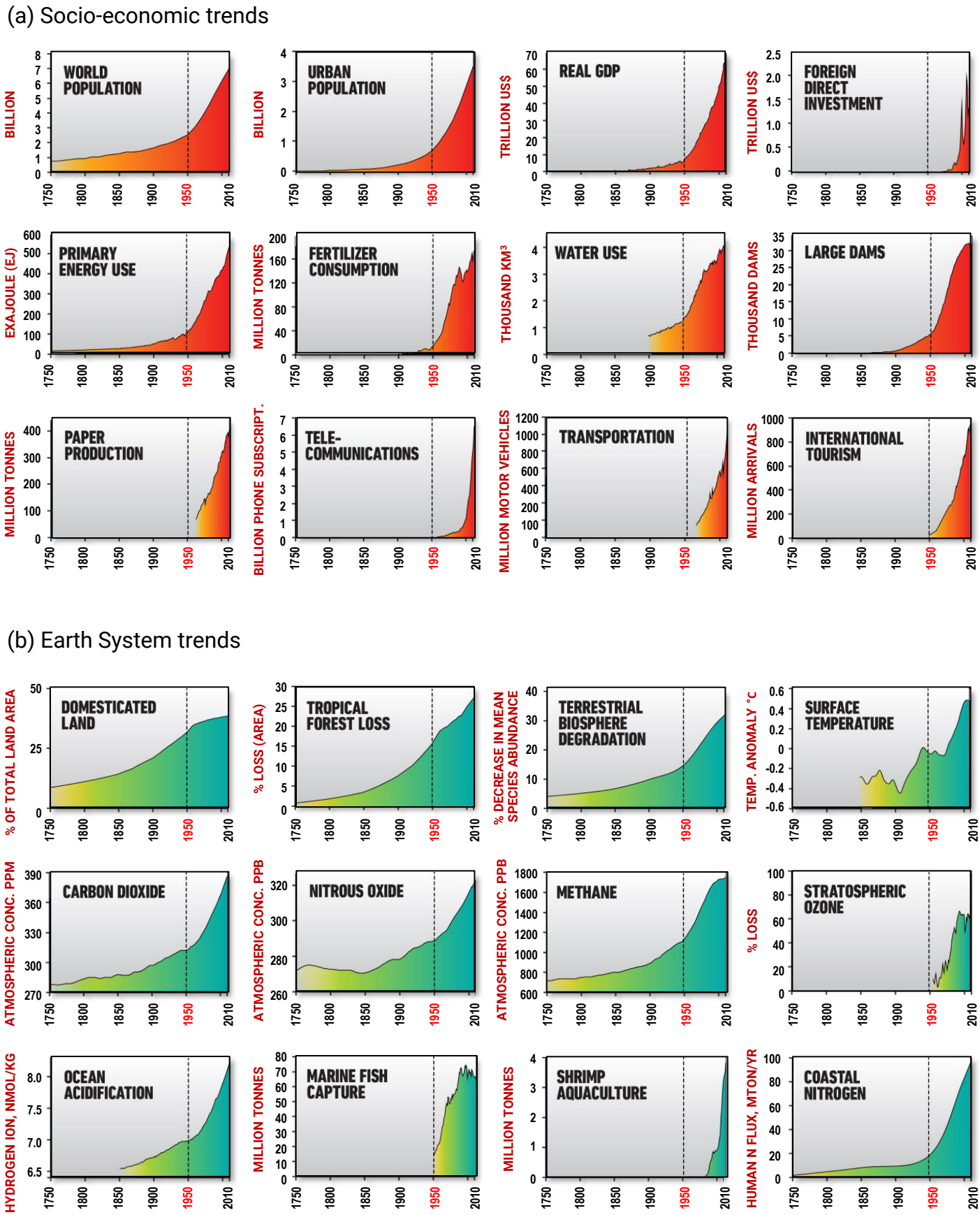

Figure 1 | Trends from 1750 to 2010 in global indicators for (**a**) socio-economic development, and (**b**) structure and functioning of the Earth System. Adapted from Steffen et al. [12]

Primary drivers of zoonotic disease emergence

Although the direct and indirect drivers of infectious disease emergence are manifold and often interacting, there is overwhelming evidence to indicate that broadscale land conversion and ecological disturbances increase the overall risks of pathogen spillover and zoonotic disease outbreaks originating from wildlife [13–22]. Indeed, in a global study of 335 human infectious disease 'events' occurring from 1940–2004, at least half of these arose from changes in land use, agricultural activities or other food production practices, or from bushmeat hunting (Fig. 2). The main mechanisms influencing such disease spillover events are (i) changes in host pathogen interactions, (ii) disruption of animal food web structures, and (iii) mixing of pathogen gene pools, leading to increased genetic diversity and virulence [16]. Once a spillover occurs, our hyper-connected global societies and transport systems make it easy for diseases to spread rapidly across the world and transition into pandemics, as COVID-19 has aptly shown us. There is also strong evidence indicating that climate change and related weather pattern alterations will augment future zoonotic risks (particularly vector-borne diseases) by inducing animals species range shifts, vector shifts, and changes in pathogen lifecycles [19,23]. An extensive literature review of emerging infectious diseases in Brazil already reveals important connections between disease outbreaks and extreme climate events [17].

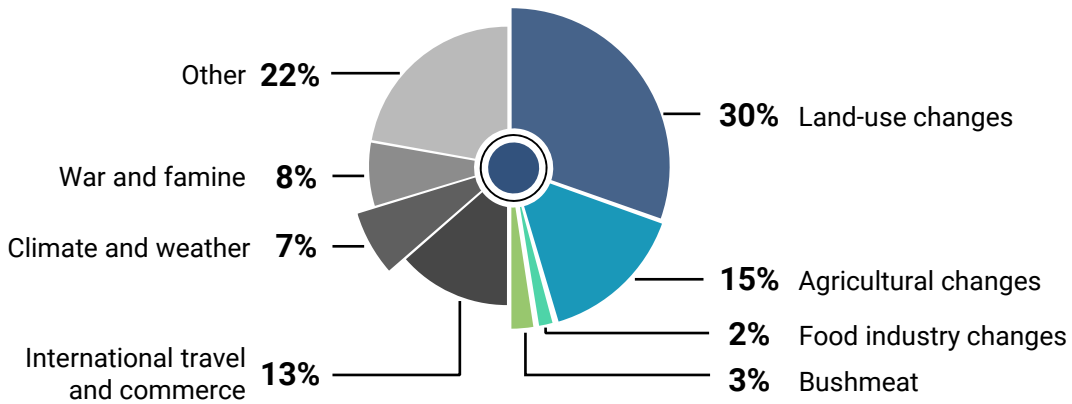

Figure 2 | Percentages of infectious disease events associated with different anthropogenic drivers [15].

Land-use change and disturbance

The primary types of land-use change that influence zoonotic disease transmission include deforestation, habitat degradation and fragmentation, agricultural expansion and urbanisation [18,24]. All these activities promote human encroachment into natural habitats, disrupt ecosystem processes, and initiate multiple pathways for pathogens to cross species barriers and cause disease outbreaks (Fig. 3).

Tropical forest experiencing land-use change are major launchpads for novel diseases [25]. Edges arise as humans construct roads or clear forests for agriculture or timber production [26]. Humans and their livestock are especially likely to contact wildlife when >25% of original forest cover is lost [27]. Extractive industries (e.g. logging, mining) also trigger atypical human influxes into forested landscapes, the growth of new settlements and often heavy exploitation of bushmeat for food [28]. Furthermore, rapid urbanisation – particularly if unplanned or with poor infrastructure – can create novel and diverse contacts among pathogens, hosts and vectors, and provide fertile grounds for zoonotic disease emergence [17,23] (Fig. 3).

Box 1: How healthy ecosystems protect our health

Intact and biodiverse ecosystems serve as a protective 'barrier' against disease in a similar, but more complex, way to how human intestinal biodiversity does – i.e. they support a diversity of species and make it more difficult for a single pathogen to dominate or spread rapidly [19].

However, when natural environments are stressed and genetic diversity is lost, the complexity and resilience of entire ecosystems is compromised, rendering them more vulnerable and increasing opportunities for disease emergence.

Agricultural expansion and intensification

Producing food for an escalating human population – and the associated increases in land conversion and industrialisation of animal production – drastically expands the wildlife–livestock–human interface and the likelihood of spillover events. Domestic livestock are both important reservoirs and bridging links in emergent diseases (Fig. 3). Examples of diseases that have crossed the wildlife-human interface via livestock include H5N1 influenza (wild bird–poultry–human) and Nipah virus (bat–pig–human) (Fig. 3). Soaring demand for animal protein stimulates more intensive production, resulting in larger populations of high yielding and genetically similar livestock kept in close proximity [19,23]. Such conditions not only favour high livestock contact rates, but the animals also lack the genetic diversity to help resist disease infection – a vulnerability known as the 'monoculture effect' [16,19]. Agricultural intensification also leads to increasing dam construction, fertiliser use, irrigation and livestock waste production – all of which drive disease emergence by providing favourable environments for pathogen hosts and vectors [8,17,19]. Moreover, ~33% of the world's croplands are used for livestock feed production, which is driving deforestation in some countries [23].

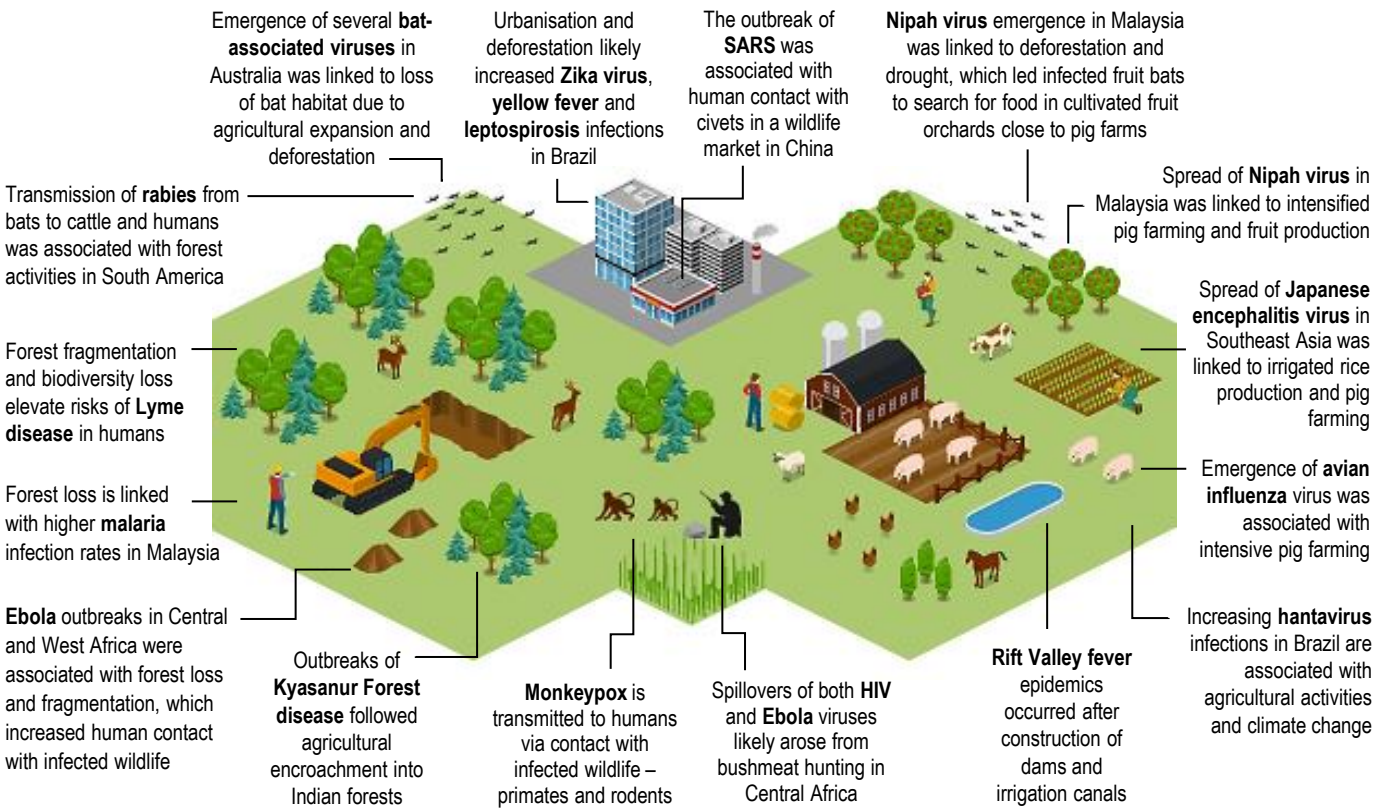

Figure 3 | Primary anthropogenic drivers of past zoonotic diseases. Data from Jones et al. [16] and Nava et al. [17]

Direct exploitation of wildlife

Across the world, wild animals are harvested and traded for food, income, medicine, ornaments, pets and various other purposes. Demand for these products may be subsistence driven or for luxury 'conspicuous' consumption [28,29]. The zoonotic risks associated with wildlife hunting, trade and consumption were detailed in Briefing 2. In short, while pathogen spillover can occur via consumption, the highest risks arise from exposure to animal body fluids during handling and butchering of carcasses [30]. The main risks associated with markets are the volumes traded, mixing of different species, on-site slaughtering, overcrowding and unsanitary conditions [31–33]. Spillovers of HIV, Ebola and monkeypox viruses likely arose through bushmeat hunting or direct contact with wild meat or blood, whereas outbreaks of SARS and COVID-19 have been linked to wildlife markets in China (Fig. 3).

Impacts of COVID-19 on conservation

It is clear from the previous sections that the world is changing rapidly, and the conservation community must be ready to respond. However, COVID-19 has brought with it a plethora of uncertainties, including on its potentially broad-ranging impacts on the environment and on how conservation will fare in the aftermath given the multiple new constraints and priorities for financial resources.

Several reports highlight some positive pandemic-related outcomes for nature, including significant global reductions in air pollution and greenhouse gas emissions owing to decreased traffic and human activities [34,35]. Certain Asian countries (e.g. China, Vietnam) have implemented measures to curb wildlife trade which, if adequately enforced in the long term, could reduce poaching for high-value wildlife products (e.g. rhino horn, tiger bone, pangolin scales) [36]. Restricted transportation and human movement, along with decreased consumer confidence, might also have altered the supply-and-demand dynamics of illegal trade supply chains [37]. In protected areas, the drop in visitor numbers due to park closures and travel restrictions has reportedly reduced stresses on sensitive animals, as well as roadkill incidents. Shipping has declined worldwide, prospectively giving marine ecosystems some respite [35].

While it is encouraging to seek 'bright spots' in an otherwise gloomy situation, many of these improvements are likely transient and prone to reversal once travel and human movement restrictions are rolled back. Overall, the pandemic's net impacts on conservation are expected to be negative and longer lasting [36]. Figure 4 illustrates some of the immediate and imminent ripple effects arising from lockdown measures and decreased economic activities, creating what has been described as '**a perfect storm of reduced funding, restrictions on the operations of conservation agencies, and elevated human threats to nature**' [36]. Arguably, conservation faces its greatest challenges in decades, some of which are discussed further below.

Financial impacts from loss of tourism

The almost complete cessation of ecotourism and consequent disruption of funding streams to conservation areas and agencies likely pose the most immediate threats to biodiversity protection and human livelihoods [38]. In addition to tourism revenue losses, governments face severe budget curtailments due to the pandemic-associated economic crisis and the costs of relief measures [36]. Wildlife authority budgets, already grossly deficient in many developing countries, consequently risk being slashed further. Philanthropic donations for conservation are also expected to be substantially reduced in both the short and long terms due to faltering economies and prioritisation of humanitarian causes over wildlife protection [34,36].

Box 2:

Conservation needs a 'bailout'

Globally, governments have responded to the impacts of COVID-19 by allocating more than **US$ 11 trillion** of economic stimulus to various sectors of the economy. Conservation has received **little to no** such stimulus packages, even though it is at the core of the UN Sustainable Development Goals [38].

Protected areas are in particularly dire need of economic stimulus funding, given their pivotal role in conserving biodiversity, maintaining ecosystems services, bolstering local and national economies, providing jobs and advancing social development agendas [38].

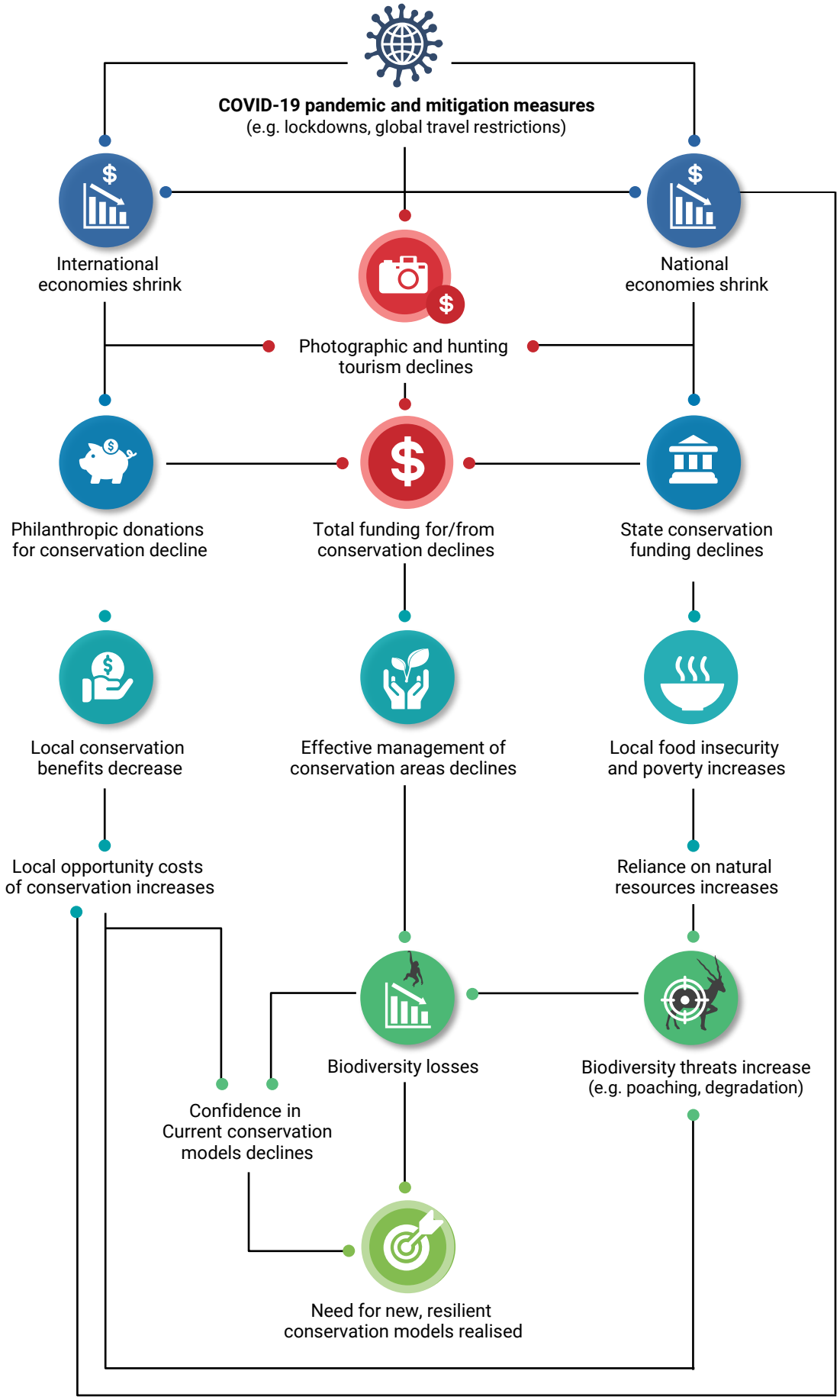

Figure 4 | Potential cascading effects of the COVID-19 pandemic on conservation. Adapted from Lindsey et al. [36]. Note that although this schematic was created to illustrate conservation impacts in Africa, these scenarios likely extend to many other regions in the developing world.

Since tourism and donor funding are the largest contributors to protected area financing in many countries (e.g. in Africa, Fig. 5), dissipation of these vital income streams holds calamitous ramifications for the operations of state and private parks and reserves, as well as community conservation programmes [36]. Dwindling funding has also resulted in the layoff of staff and reductions in essential monitoring services (e.g. game counts and ranger patrols), which in turn undermines management effectiveness. Local communities that depend on protected areas and peripheral industries for employment or share benefits from tourism have had their livelihoods severely disrupted [39]. Economic hardships and a lack of alternative job prospects accordingly increase human reliance on subsistence harvesting and foraging, thereby escalating widespread and unsanctioned natural resource extraction [38,39]. Indeed, there are reports of increased poaching and illicit resource extraction (e.g. logging) during lockdowns in parts of Cambodia, India, Nepal, Costa Rica, Tunisia, and southern and eastern Africa [39]. With many wildlife populations and habitats already near their tipping point, these added pressures on biodiversity will likely compromise the functioning of ecosystem processes and services at such locations, catalysing a vicious cycle of negative impacts for people. Moreover, this elevated exploitation of wildlife could increase human exposure to high-risk pathogen reservoirs (e.g. bats, primates, carnivores, rodents) and amplify future zoonotic outbreaks [36].

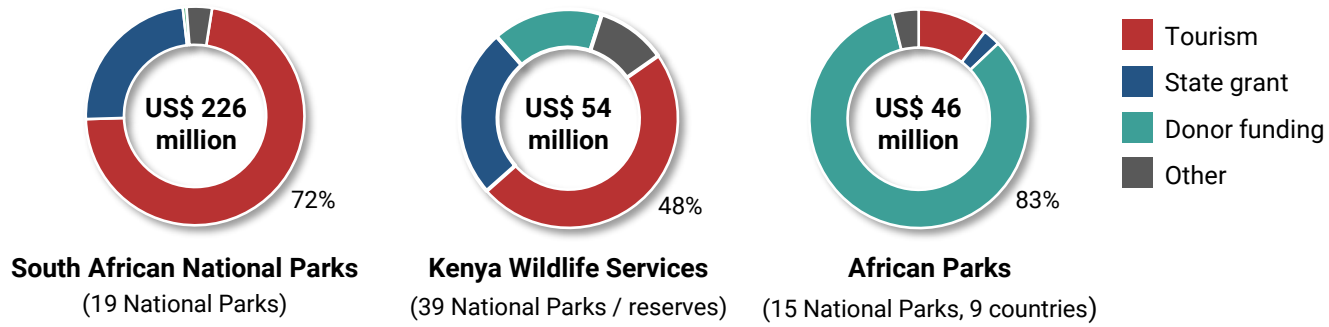

Figure 5 | Contributions of different funding streams to the annual budgets of various wildlife authorities in Africa. Data are from the annual financial reports of the respective authorities [40–42].

Direct ecological repercussions

Fears and speculations linking wildlife with disease transmission could provoke negative attitudes towards certain animals and drive 'retaliatory' killing [34]. For instance, during the SARS outbreak in China, >10,000 civets and other carnivores were persecuted after a new strain of the virus emerged in Guangdong [43]. There are already reports of retaliation attacks on bat colonies (e.g. in Indonesia, Peru, Rwanda) due to their suspected role in COVID-19's origins, while over a million farmed mink were killed across the Netherlands and Spain after numerous mink and farm workers tested positive for SARS-CoV-2 [44]. Furthermore, due to their close phylogenetic relatedness with humans, non-human primates could be susceptible to COVID-19 infection [39]. Thousands of gorillas and other primate species have died from Ebola and yellow fever in the Congo and Brazil's Atlantic forests [45,46], respectively, and similar outbreaks of COVID-19 could have devastating impacts on already threatened primate species and their habitats.

Disruptions to research and networking

While teaching and other communications have largely moved online, most major research projects – especially those involving field work – have either been postponed or cancelled. Social survey-based research is likely to remain constrained post-pandemic due to lingering fears of disease transmission [34]. Research budgets have been cut, new academic appointments put on hold, and the jobs and experience of countless temporary workers and interns jeopardised [35]. Moreover, many important conferences, workshops, and training events have been delayed or cancelled. These missed opportunities will impede conservation actions and practical solutions in the long run.

An ounce of prevention is worth a pound of cure

Although this briefing might paint a gloomy picture for the future of conservation and for humanity in general, the current crisis could also provide a critical juncture to transform our existing approaches and forge new policies that favour sustainable recovery and improved human wellbeing. Currently, we invest relatively little toward preventing ecosystem damage and unsustainable wildlife exploitation, despite clear evidence of their role in amplifying zoonoses and other negative impacts. The international community also lacks a structured and harmonised system for monitoring and mitigating zoonotic disease risks – surveillance is limited, data collection is poor, and there is substantial under-reporting of disease exposure and outbreaks. COVID-19 has shown us that it is time to change this.

If we are to prevent future pandemics and associated social and economic devastation, we crucially need to shift from a reactive to a proactive stance, to break down disciplinary and sectoral silos, and to collectively address all the root causes of zoonotic disease emergence. The most promising way to achieve this is through the universal adoption of a holistic approach such as 'One Health' (www.onehealthcommission.org), which recognises the interconnectedness between human, animal and environmental health, as well as the interplay of social and political factors. Such approaches foster cross-sector collaboration, integrated impact and risk assessments, active monitoring and surveillance, and early warning systems. Where One Health has been successfully implemented, there have been notable achievements in critical data collection, new pathogen discovery and improved outbreak responses. Along with improved surveillance and response capabilities, urgent and concrete actions are required to reduce environmental degradation and restore the integrity of the natural world. This co-ordinated response would potentially offer 'win-win' solutions for both conservation and human health, while also proving far less costly (from health and economic perspectives) than emergency responses after an outbreak has occurred. For instance, Dobson et al. [26] recently assessed the costs of various interventions to monitor and prevent zoonotic disease spillovers, the price tags of which pale in comparison to that of the current pandemic (Fig. 6). In fact, the authors estimate that the total costs of preventing further pandemics over the next decade would equate to just 2% of the global economic damage caused by COVID-19. As nations endeavour to reinvigorate their economies in the COVID-19 aftermath, there will certainly be a need for trade-offs. However, delaying strategies to reduce pandemic risks will undoubtedly lead to continued soaring costs.

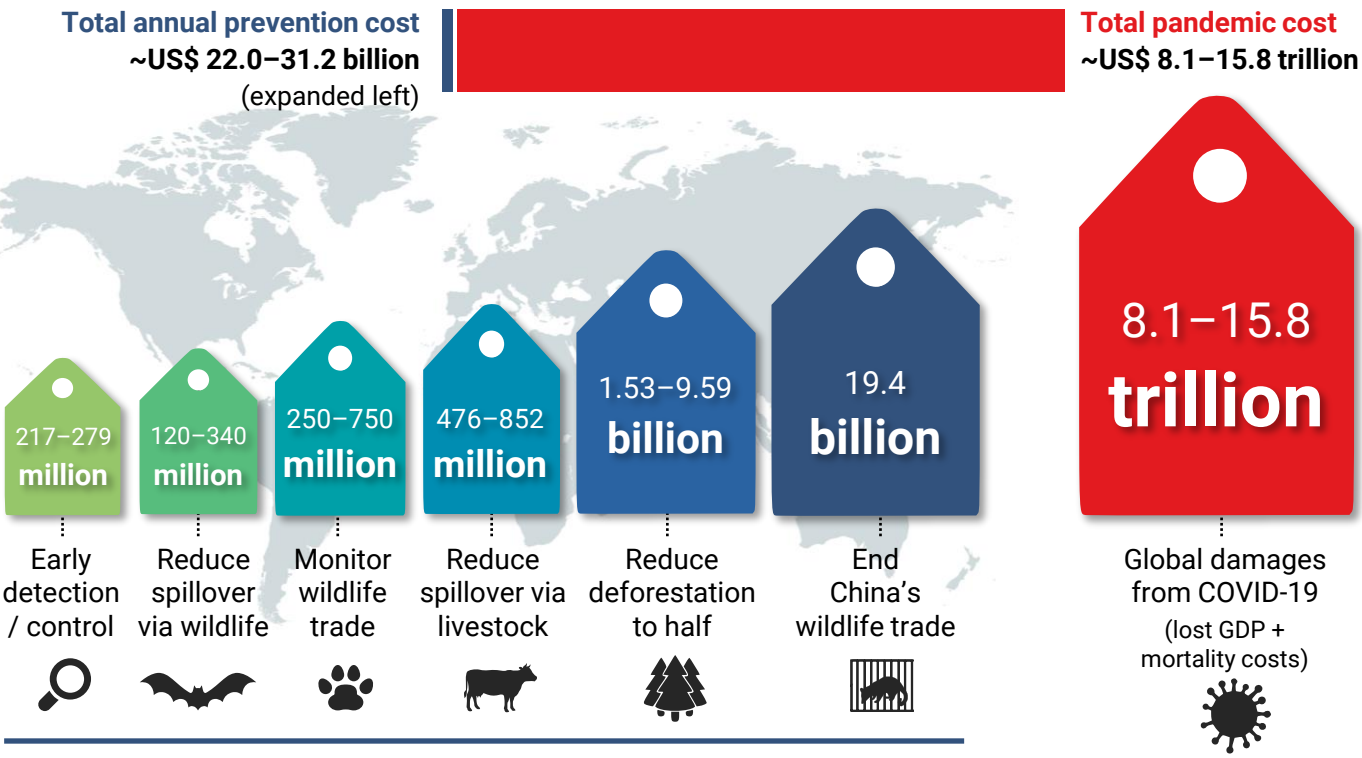

Figure 6 | Estimated annual costs of preventing future zoonoses versus the costs of the COVID-19 pandemic [26].

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