BANS AND BACKFIRES:

Precautionary lessons on managing zoonotic risks from wildlife trade

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Briefing 2: Wildlife, origins of COVID-19, and preventing future pandemics

The ongoing COVID-19 pandemic has thrust issues of wildlife trade and zoonoses firmly into the spotlight, particularly in so-called 'wet markets', and sparked calls for immediate global actions to reduce the associated public health risks. COVID-19 is the third coronavirus-related epidemic to emerge from a pathogen 'jump' from wild animals to humans, following outbreaks of severe acute respiratory syndrome (SARS) in China in 2002, and Middle East respiratory syndrome (MERS) in Saudi Arabia in 2012 [1]. Early reports suggesting that the virus arose in a wet market in Wuhan, China (the Huanan Seafood Market) [2,3], inevitably fuelled public concerns and prompted several governments to effectuate swift legislative changes relating to the use of wild animals. These included the widespread shutdown of wet markets [4] and blanket prohibitions on the sale and consumption of terrestrial wildlife in parts of Asia and Africa (Fig. 1) [5,6], accompanied by voluminous outcries to extend such injunctions globally and permanently [7–10].

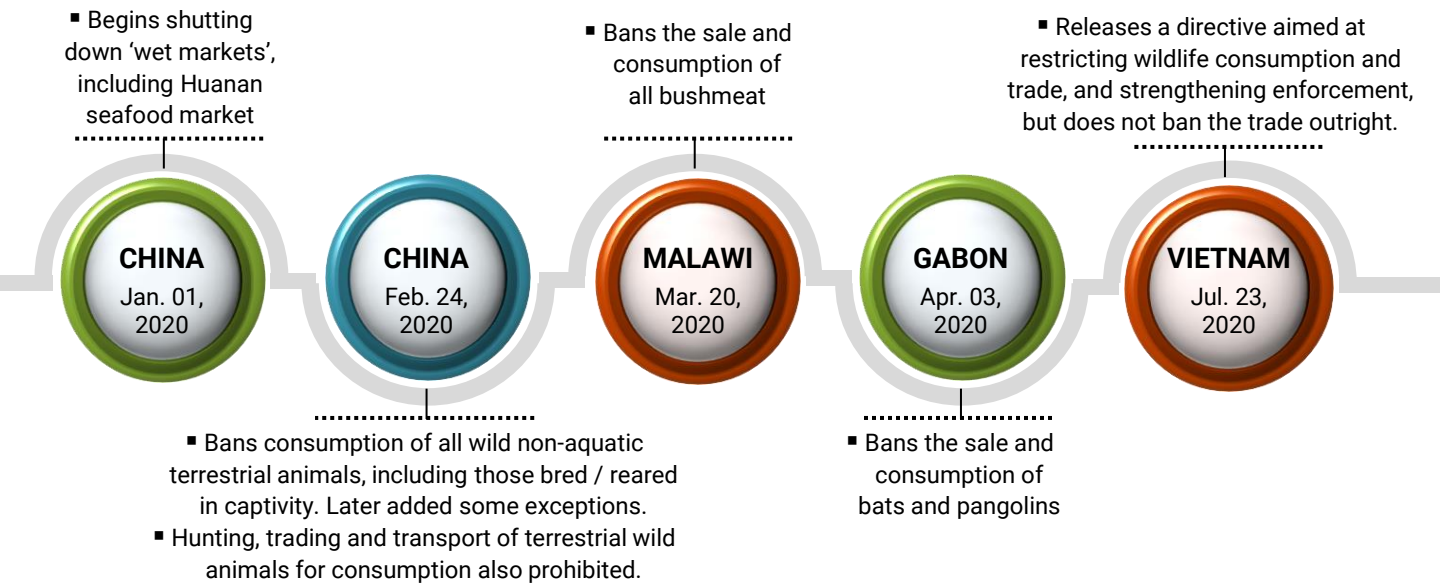


Figure 1 | Legislative changes and actions taken by various countries in response to the proposed links between COVID-19 and wildlife trade.

The current pandemic has already unleashed enormous social and economic devastation worldwide, especially among poor and vulnerable communities, and its multiple impacts stand as a direct threat to the achievement of several of the Sustainable Development Goals (SDGs) set by the United Nations [11]. There is thus certainly a pressing need to mitigate future zoonotic outbreaks and to stamp out wildlife trade that is illegal, unsustainable or that jeopardises human health, animal welfare or biodiversity conservation. However, it is vital that any measures taken in pursuit of these goals are appropriate and equitable, and neither exacerbate poverty nor detract from the development of economically resilient livelihoods for the myriads of people that rely on wildlife for survival [12]. Some of the calls for action, such as banning wildlife use in its entirety, go far beyond tackling disease risks and instead have the potential to trigger a cascade of unintended consequences that compromise conservation incentives and future pandemic preparedness [13]. This briefing aims to synthesise the current evidence on wildlife trade and zoonoses, to highlight some of the knock-down effects resulting from rushed interventions, and to provide pathways for mitigating future wildlife-associated disease risks.

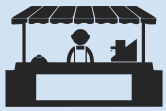
Evidence on the origins of COVID-19

Much remains uncertain regarding the emergence and spread of the COVID-19 pandemic that continues to wreak havoc across the globe. What is known so far is that there was a single introduction of the virus into humans, followed by rapid human-to-human transmission [14]. There is also relatively conclusive evidence that SARS-CoV-2, the causative agent of COVID-19, is of wildlife origin and that bats are the natural reservoirs [15]. The genome of SARS-CoV-2 is ~96% similar to that of coronaviruses isolated from horseshoe bats (*Rhinolophus affinis*) in China [16], but it is not identical to them. SARS-CoV-2 could therefore be a new virus that arose from a recombination event (i.e. via the exchange of genetic material between a bat virus and a similar virus in another species), which occurs relatively frequently in coronaviruses [17]. The intermediate host(s) of the virus (if any), as well as the precise mechanisms of spillover to humans, nevertheless remain a puzzle unresolved. Although pangolins have been suggested as intermediate hosts since they harbour coronaviruses comparable to SARS-CoV-2, there is insufficient genetic evidence to confirm these species as direct precursors [15]. A range of other intermediate host candidates (mainly mammals) has also been proposed [18].

During the early days of the pandemic, all eyes were on the Huanan Market in Wuhan as the source of the outbreak. Along with seafood, this market also sold domestic and wild animals [19], and therefore might be better described as a 'wildlife market' than a 'wet market' [see Box 1]. The basis of the speculation was that some of the early cases in Wuhan either worked at, or had visited, the Huanan market [2] and since 33 of 585 environmental samples taken from the market's western portion (where wildlife was sold) tested positive for SARS-CoV-2 [19]. Moreover, since the coronavirus responsible for the 2002 SARS outbreak was evidently also of bat origin and likely emerged at a similar market in China [20,21], the Huanan market explanation appeared most plausible [19].

More recent findings, however, indicate that the market may not have been the source of the virus, but rather the site of a super-spreader event, where one infected person transmitted the virus to many others [22]. For one, tissue samples taken from the market's animals tested negative for the virus. Secondly, published clinical descriptions of the early cases in Wuhan showed that both the first patient to be diagnosed, and around 40% of all initial cases, had no exposure to the Huanan market [2,3]. This suggests that the virus was already circulating among humans, either in Wuhan or elsewhere, before the cluster of cases from the Huanan market was discovered in late December 2019 [14]. Nevertheless, it is clear that the Huanan market played a central role in the initial transmission of the virus, even if not the origin.

Box 1:



Beyond 'wet markets'

Since the possible link between COVID-19 and the Huanan Seafood Market was first suggested, there has been considerable confusion about the true meaning of a 'wet market', which is often unduly conflated with a 'wildlife market'. The differences between these markets are crucial to accurately assessing zoonotic disease risks, thus it is important to set the record straight.

The term **'wet market'** typically refers to marketplaces across Asia that sell fresh meat, fish, produce and other perishable goods, distinguishable from 'dry markets' that sell durable goods like fabric and electronics. They play a key role in urban food security due to factors of pricing, freshness of food, social interactions and local cultures. Most Asian wet markets do not sell wildlife, and they are not necessarily unsanitary places or disease risks. Equivalents to 'wet markets', such as 'farmers markets', are found worldwide.

'Wildlife markets' are found in many countries and specifically sell wild animals (live or dead) or their products for meat/food, medicine or as pets. Wildlife markets can sell a wide diversity of taxa, both wild-harvested and captive-bred, ranging from insects to elephants. These markets may be legal, although they sometimes offer illegal species alongside permitted ones.

'Bushmeat market' is often used to describe a market that exclusively sells wild animal meat for human consumption. These markets are found in many setting across Africa, Latin America and Asia. Although the term 'bushmeat' was originally coined to describe the remains of wildlife harvested in African forests and savannas, it is now colloquially used to refer to any wild animal meat.

'Markets' are not only physical ones, but in the broadest terms also include online platforms or e-commerce etc.

Scale and magnitude of the wildlife trade

The global trade in wildlife, both legal and illegal, is an extensive and multibillion-dollar industry, which not only poses zoonotic disease risks, but also threatens biodiversity [23]. Of more than 31,500 extant mammal, bird, amphibian and squamate reptile species, over 7,600 (ca. 24%) are traded across the world [24]. Accurately quantifying the magnitude of the global wildlife trade is virtually impossible, since it varies in scale from local barter to major transnational routes, and much of this is conducted clandestinely or via informal networks [25]. Nevertheless, the value of the legal component of this trade, excluding timber products, is conservatively estimated at ~100 billion US dollars per year [26]. Considering the trade in CITES-listed species alone, over 2.9 million individual live wild animals are reportedly exported per year, representing 1,350 different species and comprising 76.9% reptiles, 20.3% birds, 1.5% amphibians and 1.3% mammals (Fig. 2). More than 190 countries participated in the international live wild animal trade between 2016–2018, with China, Hong Kong and the USA being the dominant role players [27].

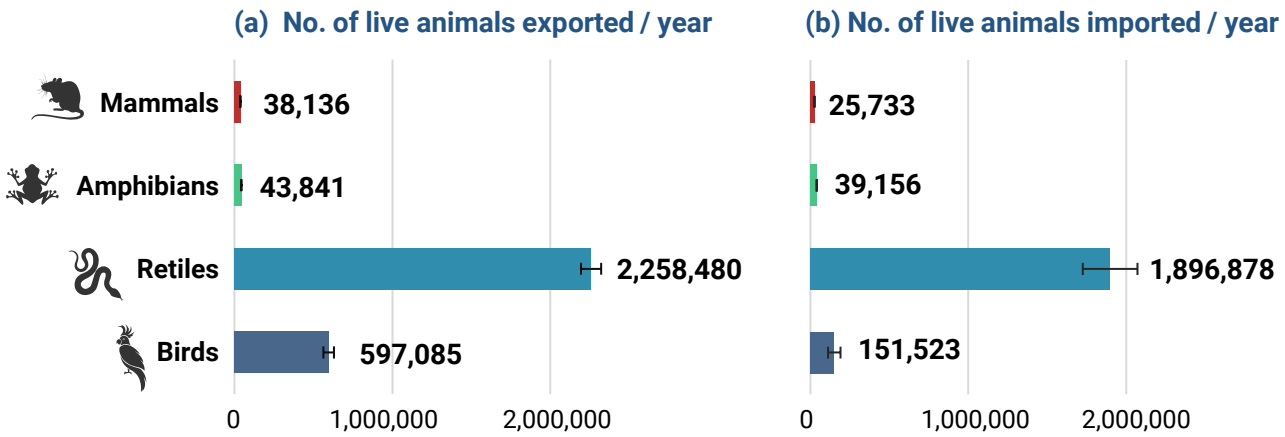


Figure 2 | Global trade in CITES-listed live wild animal species. Breakdown of the average annual reported exports (a) and imports (b) of live animals categorised as being traded for commercial or personal purposes. Data are derived from the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) trade database [27] and cover the period 2016–2018. Error bars indicate standard deviations. Export and import quantities do not match because not all Parties submit complete reports to the CITES Secretariat, some transactions may not transpire, or fewer specimens may be shipped than specified on permits.

Wildlife markets of various types are similarly widespread across the globe, with particular hotspots in the tropics. Figure 3 shows the locations of some key wildlife markets (mostly wild meat markets) that have been identified in the scientific literature (black circles), but undoubtedly only provides a glimpse of the true extent of this trade. High volumes of live or dead wild animals flow daily through many of these marketplaces (coloured circles, Fig. 3a), where they inevitably come into contact with dozens of people and other species. The bulk of animals traded in wildlife markets are mammals (Fig. 3b), which is also the class of animals hosting the largest number of zoonotic pathogens (see Technical Briefing 1). Nevertheless, Southeast Asian markets generally tend to sell comparatively higher proportions of reptiles and birds [28] than those in Africa and South America.

In a single wildlife market in Bangui, Central African Republic (CAR), >538,000 wild animals (4,000 tons) are sold per year [29], including over 239,000 ungulates, 102,000 rodents, 75,000 primates and 84,000 wild birds (Fig. 3b). This annual turnover of wild animals is likely to more than double when all markets across Bangui are considered [30]. Moreover, Bangui is just one of numerous regions in Africa associated with the large-scale exploitation of wildlife (Fig. 3a). Across the wider Afrotropical forests, it is estimated that up to 4.9 million tonnes of 'bushmeat' (or 'wild meat', see Box 1) is harvested annually for trade and local consumption [31].

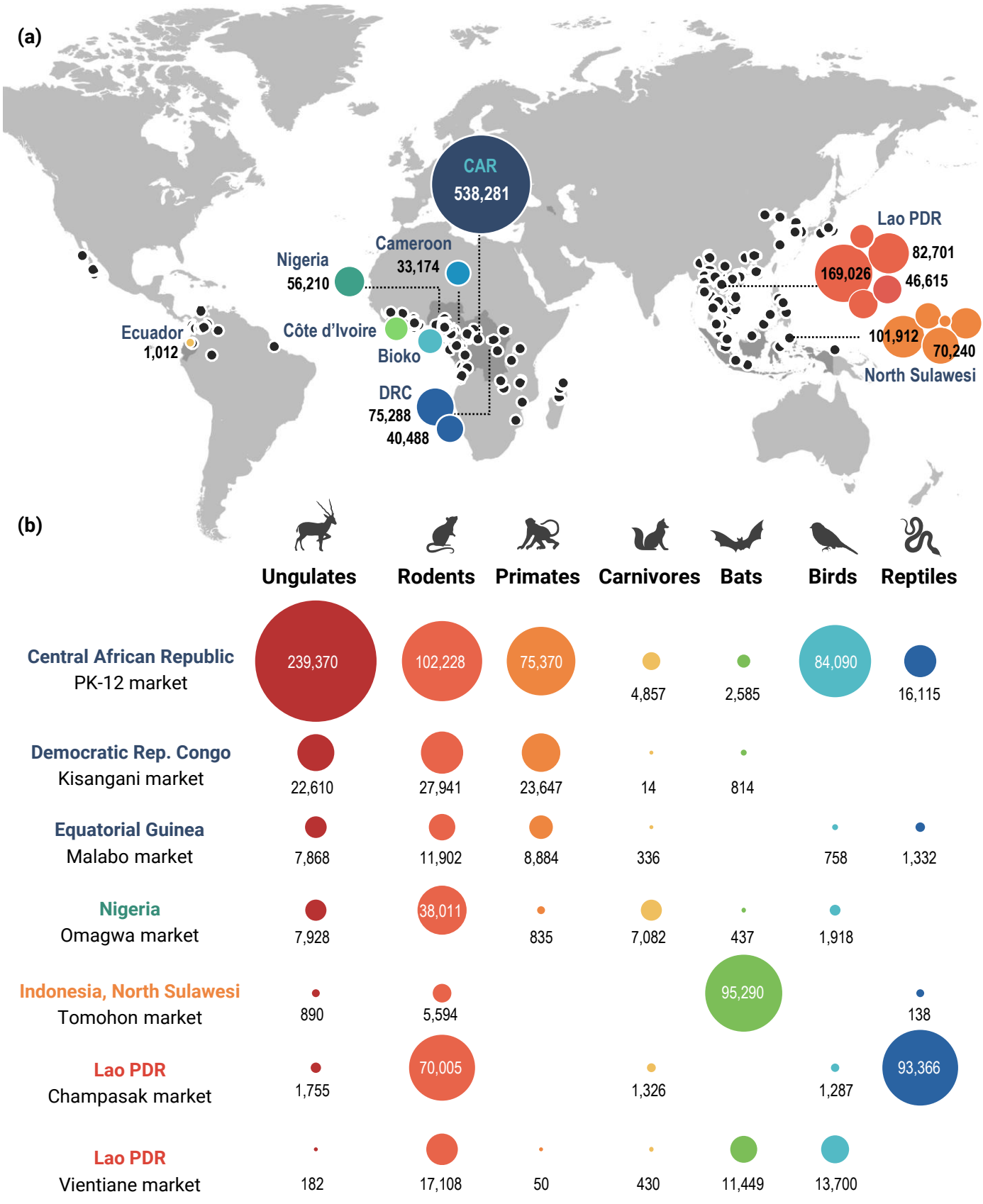


Figure 3 | The global distribution of wildlife markets. (a) The coloured circles indicate the estimated number of wild animals traded per year in key high-volume markets across Latin America, Central-West Africa, and Southeast Asia. The size of the circles is proportional to the annual trade volume (no. of animals). The black circles show the locations of other important wildlife markets worldwide, but do not provide quantitative data. This list is non-exhaustive and does not purport to represent the full extent of the trade, but rather includes those markets (mostly wild meat markets) that have been investigated in the scientific literature. **(b)** Number of animals traded in various markets by mammalian order and in the classes Aves and Reptilia. Additional information on the markets and data sources is given in Appendix 1. CAR = Central African Republic; DRC = Democratic Republic of Congo.

In Southeast Asia, ca. 200 market locations have been identified in Myanmar that sell wild animals [32] and at least 93 wildlife markets have been documented in Lao People's Democratic Republic (Lao PDR) [28]. Just one of these in Lao PDR's Champasak province trades upwards of 169,000 wild animals (72 tons) per year [28]. Indonesia represents a further key hotspot for wildlife trade in Southeast Asia, especially the islands of Sulawesi, Sumatra, Java and Bali [33–37]. The Tomohon market in North Sulawesi alone sells ca. 95,000 bats and 5,500 rodents per year (Fig. 3b), while estimates of the annual trade across all wildlife markets in North Sulawesi are in the order of 662,551 bats; 21,000 rats; 8,380–41,900 wild pigs and 900–10,285 snakes [34].

Zoonotic risks along wildlife supply chains

Considering its scale and magnitude, there is little doubt that the wildlife trade has inherent risks of bringing people into close contact with wildlife and their pathogens, including many that have not been previously encountered, and also has the potential to lead to future disease outbreaks, epidemics and pandemics. Some of the primary concerns associated with the trade are discussed below.

High species diversity, including risky taxa

The risks of human exposure to wildlife pathogens depends on both the quantities and the specific types of animals that are traded and consumed [38]. Many wildlife markets carry a diverse mixture of species from various taxonomic classes, including exotic taxa, meaning that there is potential for a high diversity of pathogens to be present at such sites. For instance, at the Lak Xao market in Lao PDR's Bolikhamxay province, at least 178 different species were recorded over a 6-month period [39] (Fig. 4). Particularly high taxonomic diversity has also been documented in markets across South China [40,41] and Gabon [42]. The wide array of rodents, carnivores, primates, bats and ungulates sold at many of these markets are of particular concern (Fig. 4), as these mammalian groups stand out as high-risk zoonotic pathogen reservoirs (see Technical Briefing 1), and the addition of birds and reptiles at some locations is likely to amplify the potential pathogen load. The mixing of different species from various geographical origins and habitats increases the probability of intra- and inter-species transmission of pathogens and recombination events [43]. For instance, the outbreak of SARS in China in 2002 was associated with a coronavirus spillover from bats to civets [21], before being transmitted to humans, but numerous markets carry various bat and carnivore species side-by-side (Fig. 4).

Complex supply chains

The complexity of wildlife distribution channels is another important factor elevating the risks of zoonotic pathogen transmission. At each step in the supply chain – from capture, through collection and transport points, and finally to end markets – there are opportunities for multitudes of individuals to come into close contact with wildlife pathogens, including the hunters, middlemen, vendors and consumers. Market consignments containing various taxa can spend several days in transit from source to destination, and then remain on the market for several more [38], often with little maintenance of the cold chain. Stressful conditions and poor nutrition during harvesting, transport and within markets can also compromise animal's immune functions and result in increased pathogen shedding (or excretion) and amplification of disease risks along the supply chain [44]. In a recent study (pre-print) on field rats destined for human consumption in Vietnam, the odds of coronavirus RNA detection where found to increase significantly along the supply chain from animals sold by traders (20.7% positive) to large markets (32.0%) and finally to restaurants (55.6%), suggesting maximal risk for end consumers [45]. Furthermore, the funnelling of wildlife and associated pathogens into urban centres creates greater opportunities for cross-species transmission and can potentially introduce novel diseases into densely-populated areas of mostly naïve individuals [38].

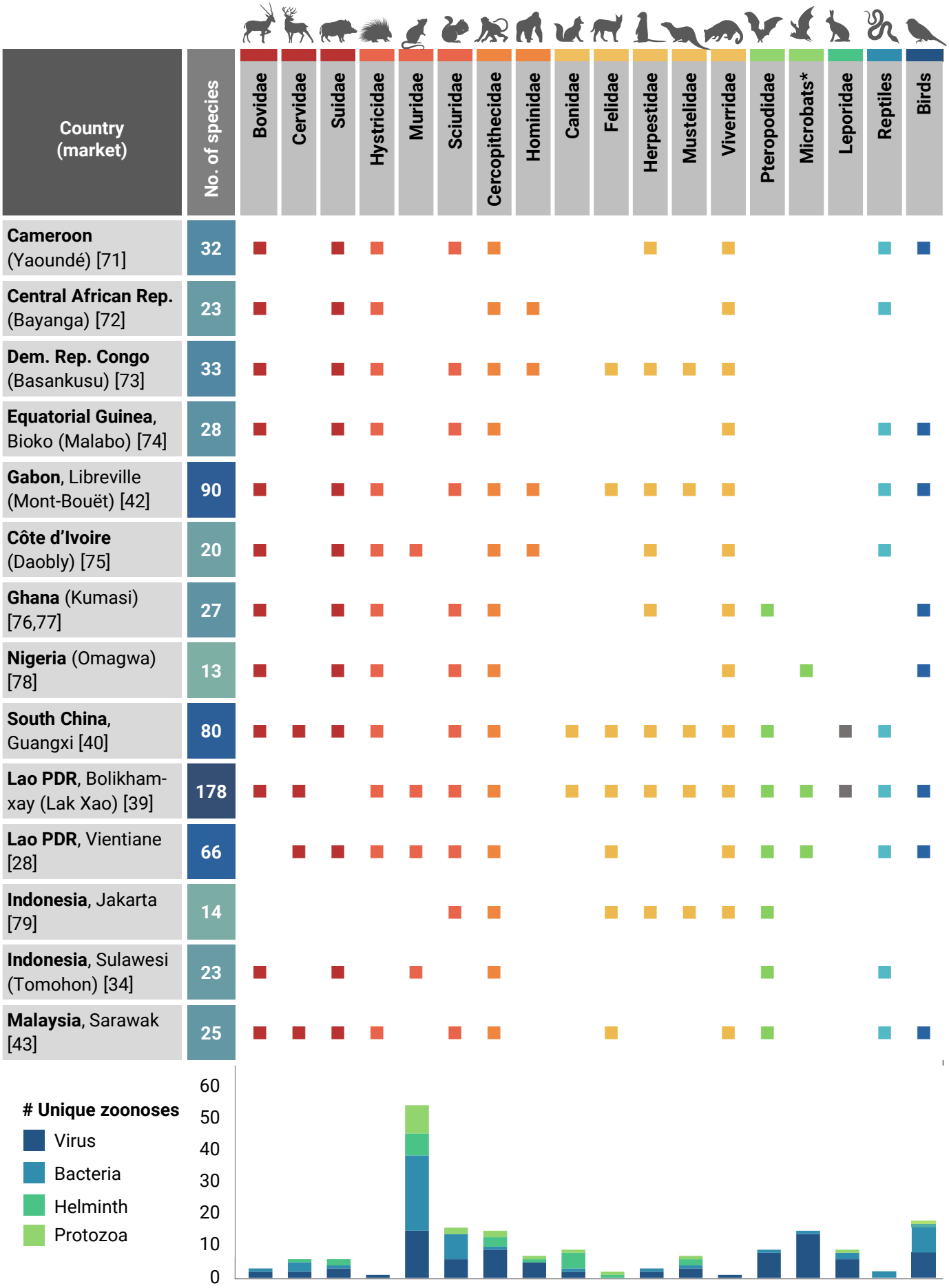


Figure 4 | Taxonomic diversity found in global wildlife markets. The top panel shows the total number of species documented in each market, as well as the different taxonomic families (for mammals) and orders (for reptiles and birds) recorded in these markets. The bottom graph shows the number of unique zoonotic pathogens associated with each family or order. Only pathogens with medium to high certainty of causing human disease are included .

Risky market conditions

Overcrowded or cramped conditions within markets increase contact rates between different wildlife species and with humans, elevating the possibility of novel pathogen exposure [44]. Risks of contact apply not only to the vendors handling the animals or their products, but also to consumers. In a typical market in Lao PDR, for instance, each wild animal receives ca. 7 contacts with consumers per hour [38]. The risk of pathogen spillover in markets is likely highest when carcasses are slaughtered, eviscerated and butchered on site, since this exposes individuals to animal blood and other bodily fluids. Vendors also tend to regularly cut themselves accidently during the process, increasing the chances for blood-to-blood interactions [46]. Additionally, bushmeat is often displayed on tables in the open, sometimes alongside vegetables and other produce, and without any means to maintain the cold chain [38]. In Lao PDR, only about half of the observed markets had running water, vendors rarely cleaned their instruments or work surfaces, and most markets had areas with animal blood or entrails on the floor [28]. Knowledge and perceptions of disease risk are also typically low amongst most bushmeat traders and market vendors [46].

Unintended consequences of hasty interventions

Some focus on the wildlife trade and animal markets is clearly warranted, given their potential role in the emergence and spread of zoonotic diseases [12]. However, in the race to develop polices to deal with the current pandemic and to identify leverage points to prevent future zoonotic outbreaks, there is a danger of implementing interventions that have unintended consequences for both people and the planet. Most notable of these is the clarion call to shutdown wet markets and to ban the wildlife trade in its entirety, which is not only unrealistic but also potentially self-defeating. History illustrates that such heavy-handed sanctions are rarely effective, since they fail to acknowledge the complexity of the trade, the centrality of wildlife in human livelihoods, as well as the social, economic and political contexts in which they are implemented [47–49]. One potential reason that these calls have gained such traction is because they dovetail with conservation efforts, and ending this trade might appear as a victory in protecting wildlife health [12,13]. But this does not mean that the evidence is there.

Indiscriminate closure of wet markets is unwarranted

Calls for the closure of ‘wet markets’ [e.g. 50] are likely premature, given the hitherto unsubstantiated links between COVID-19’s origins and the now infamous Huanan Seafood Market [22]. While governments need to ensure that markets do not pose public health risks, such overreactions could result in the wholesale termination and destruction of marketplaces across the globe [51]. Wet markets, not all of which sell wildlife (Box 1), underpin the informal food systems upon which countless urban and rural dwellers rely worldwide. Shutting down such markets will have substantial network effects that reverberate to consumers and back to local producers [51], thereby amplifying the pandemic’s impacts on vulnerable communities with no commensurate benefits [12].

Wildlife bans often backfire

Top-down rules that conflict with the beliefs and values of those expected to follow them are bound to be met with resistance and distrust [48]. Indeed, there is limited evidence that either zoonotic outbreaks or bans notably reduce wildlife consumption or trade [52,53], including that of suspected zoonotic disease hosts – such as bats, primates and civets [54–56]. On the flipside, demand for certain wild species could increase due to perceptions of scarcity, particularly if a legal supply is removed (e.g. if captive breeding is banned, as some recommended), thereby triggering market booms and incentivising further poaching [57]. Where demand persists and law enforcement is weak, there is considerable risk of driving the trade deeper underground and enmeshing this with other organised criminal networks [12,13], as occurred following the 2013–2016 Ebola outbreak [48]. It is precisely these circumstances that will impede monitoring and regulation of the trade, promote unsanitary practices and poor animal welfare, and ultimately amplify the potential for zoonotic disease outbreaks [48].

Bans could affect the food security and livelihoods of millions

Critically, the wildlife trade does not only cater for the luxury needs of the world's urban elites, but it also provides essential resources for many of its poorest and most marginalised communities. Across the tropics and sub-tropics, bushmeat and other wildlife products serve as a vital and often irreplaceable source of food, income, medicine and cultural identity for hundreds of millions of people, the importance of which generally increases in times of hardship [58–64]. By some estimates, bushmeat contributes up to 60–80% of the daily protein intake in the Congo and Amazon basins [65], and it can represent the sole household revenue stream for many rural dwellers living at the margins of the cash economy [58]. Strictly enforcing blanket proscriptions on wildlife use, especially amid unaddressed social inequalities and limited alternative livelihoods, would likely have devastating and disproportionate reverberations on the food security and wellbeing of countless people [66–68], potentially plunging them deeper into poverty and criminality [48]. This is not to say that bushmeat exploitation does not have serious impacts on biodiversity [23,24], nor is it to overlook the fact that both urban and rural consumption need to be addressed urgently and appropriately. However, imposing legal sanctions as a means to induce behaviour change in an emergency context is unlikely to be the solution in any scenario [48]. Rather, there is increasing consensus that the cautious and sustainable use of wild species may be the best way to protect biodiversity and mitigate zoonotic disease risks [69].

Reducing wildlife consumption could trigger agricultural expansion

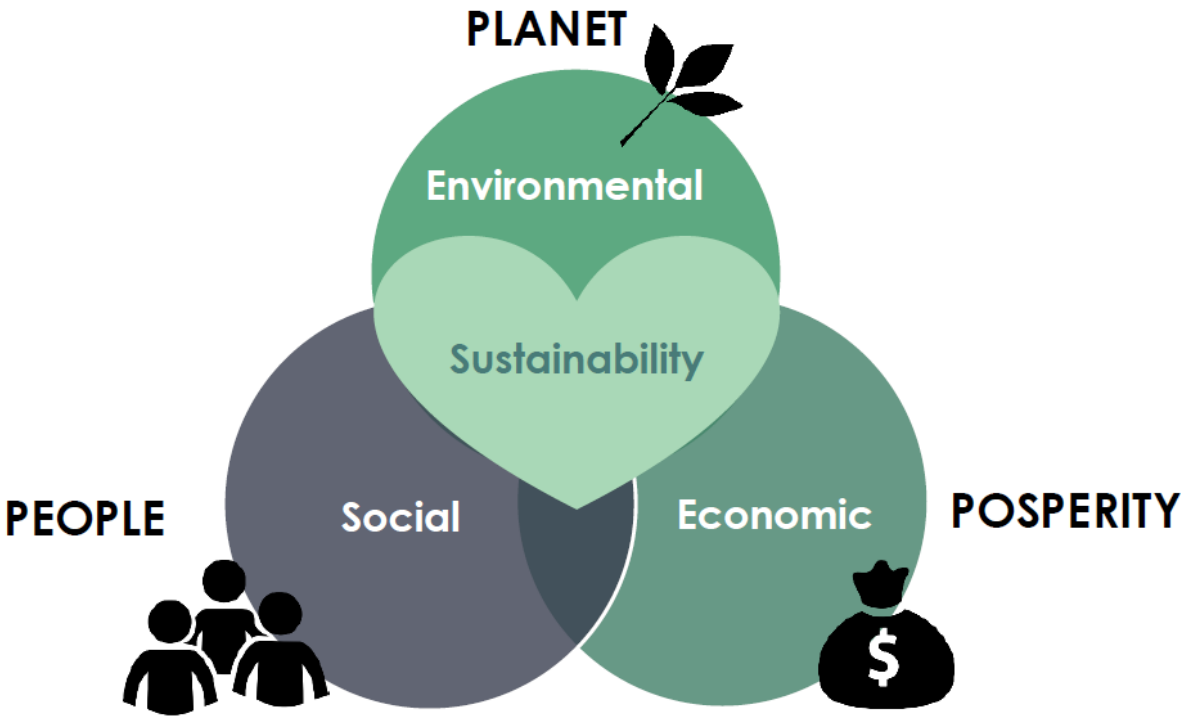
Simplistic recommendations of replacing wild meat with livestock protein may additionally carry unintended consequences, as agricultural expansion and habitat destruction are also key drivers of zoonotic disease transmission [12]. Moreover, in many African countries, expansion of the livestock sector may be unfeasible, even apart from the issues of low animal productivity, livestock disease and meagre investments. In the Congo Basin, for example, an area as large as 25 million hectares would have to be converted to pasture in order to replace the current bushmeat harvest with locally produced beef [70]. Importantly, livestock species are also significant reservoirs of zoonotic pathogens and have been implicated in numerous emerging infectious diseases [71]. Thus, a switch from wildlife to domestic meat will not necessarily eliminate zoonotic risks.

A more realistic and equitable way forward?

An alternative to indiscriminate bans could be to enhance the regulation and monitoring of wildlife commodity chains, especially those involving live animals and bushmeat.

A first step might be to identify those wildlife species with the highest risk of zoonotic pathogen transmission, and to implement measures to reduce human contact and risky behaviours associated with these taxa – not through harmful bans – but via community engagement that is respectful of different cultures and livelihoods. Policy responses could also focus on improving health, sanitation and traceability systems along distribution chains, as well as on the formulation of protocols for the hygienic handling, butchering and processing of wild animals [48]. With the increasing prevalence of zoonotic disease emergence from both wild and domestic species, systematic global monitoring and surveillance systems should be improved [46], as well as early warning mechanisms. Regardless of the measures taken, it is vital that these are complemented with culturally appropriate awareness campaigns that inform and educate supply chain actors and consumers on zoonotic transmission risks and the consequences of food choices and habits. Incentivising human behaviour change towards more cautious and safe wildlife use will require local understanding and context on the drivers and motivators of wildlife use, thus helping to ensure that policies are relevant and realistic. Such initiatives may also encourage people to use wildlife more sustainably and respectfully.

Ultimately, if we are to successfully reduce zoonotic risks globally, policy interventions need to address all root causes of disease emergence, including anthropogenic and environmental drivers (e.g. human encroachment, habitat destruction, industrial livestock production), rather than focusing narrowly on the wildlife trade. As devastating as the COVID-19 pandemic is, emergence from this crisis provides an unparalleled opportunity for a paradigm shift in both our global food production systems and conservation approaches. We need to change our destructive relationship with nature and develop appropriate strategies to sustainably and equitably manage the biodiversity upon which countless livelihoods depend. Reponses must be evidence-based, inclusive and just, bringing those most affected to the discussion table, and utmost care must be taken not to exacerbate poverty or existing inequalities.



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Appendix 1 (relating to Figure 1)

Markets and data sources included in the Figure are as follows:

South America: Ecuadorian Amazon – Pompeya wild meat market [80]; **Central Africa:** Central African Republic (CAR), Bangui – PK-12 market [29]; Cameroon – Yaoundé central market [71]; Democratic Republic of Congo (DRC) – Kisangani central market [81], Kindu market [82]; Equatorial Guinea, Bioko Island – Malabo market [74]; **West Africa:** Côte d'Ivoire/Liberia – Daobly market [75]; Nigeria – Omagwa market [78]; **Southeast Asia**: Lao PDR – Champasak, Salavan, Vientiane, Xiangkhouang markets [28]; Indonesia, North Sulawesi – Tomohon, Langowan, Karombasan, Kawangkoan, Tareran markets [34].