An immediate way to lower pandemic risk: (not) seizing the low-hanging fruit (bat)

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What is the least that humanity can do to mitigate the risks of future pandemics, to prevent worldwide surges in human deaths, illness, and suffering—and more waves of multitrillion US dollar impacts on the global economy? The issues around our consumption and trading of wildlife are diverse and complex, with many rural communities being dependent on wild meat for their nutritional needs. But bats might be one taxonomic group that can be successfully eliminated from the human diet and other uses, with minimal costs or inconvenience to the vast majority of the 8 billion people on Earth. The order Chiroptera merits genuine respect given all that these species contribute to human food supplies through pollination services provided by the frugivores and to disease risk mitigation delivered by insectivorous species. The global community missed its chance to stop SARS-CoV and SARS-CoV-2 from emerging—how many more times will humanity allow this cycle to repeat? How long will governments ignore the science that is in front of them? It's past time for humans to do the least that can be done. A global taboo is needed whereby humanity agrees to leave bats alone, not fear them or try to chase them away or cull them, but to let them have the habitats they need and live undisturbed by humans.

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Introduction

Frustratingly, more than 3 years into the COVID-19 pandemic humans are still not doing everything possible to actually prevent the next pandemic, which is not the same as addressing pandemics once they have been sparked.[1,2] The ideas that have been put forward by WHO and other key multilateral and philanthropic institutions, with billions of US dollars being committed in the name of pandemic prevention, have actually been focused on preparedness and response. We describe these as post-emergence downstream, albeit important, activities (eg, improving public health systems; advancing diagnostic capabilities; enhancing public health data collection, management, standardisation, and transparency; strategic stockpiling of personal protective equipment; rethinking supply chains; reinforcing advances in vaccinology and other biomedical interventions; and robust planning for vaccine equity).[3,4] If prevention of a pandemic is still easier and much less expensive than dealing with a pandemic itself (and we believe that it still is), then it should be asked whether humanity is up to the task of taking the most basic, common-sense steps upstream to lower the risk of another pandemic, at the interface where zoonotic viruses move from other animals into people. Although we agree with the policy prescriptions that emphasise securing the remaining forests in the world, addressing commercial wildlife trade, improving biosecurity around livestock agriculture, and improving human health and economic security,[5] none of these ideas are new; they all made sense well before the start of the COVID-19 pandemic, which only reinforces their importance, and yet all will take substantial time and resources to successfully address. But time is short. Simply put, humanity needs to urgently change its relationship with nature, specifically wildlife, and particularly bats. In a globalised world with 8 billion people, maintaining an aggressively exploitative relationship with nature is potentially societally suicidal. But direct and indirect contact with high-risk wildlife, such as bats, can actually be drastically decreased,[6] concomitantly decreasing the likelihood of viral spillover causing another pandemic.[5]

Is a new global taboo possible?

Getting humans to work collaboratively at a global scale underpins most of the existential challenges that face us as a species, from climate change to environmental pollution, to biodiversity loss, to averting nuclear war—

Key messages

- The plan ideas that have been put forward by WHO and other key multilateral and philanthropic institutions, with billions of dollars being committed in the name of pandemic prevention, have thus far been largely focused on preparedness and response, not prevention.
- Policy prescriptions emphasising securing the world's remaining forests, addressing commercial wildlife trade, improving biosecurity around livestock agriculture, and improving human health and economic security will take substantial time and resources to successfully address—but time is short.
- Humanity needs to substantially decrease direct and indirect contact with high-risk wildlife, such as bats, to decrease the likelihood of viral spillover causing another pandemic.
- Focusing on bats is truly the most fundamental step for genuine upstream prevention of pandemics; bats are uniquely placed given what is known about the wealth of zoonotic viruses that they harbour and that, comparatively speaking, few people worldwide would suffer if bats were no longer consumed. Mitigation of viral spillover risks would be quite feasible through changes in our own behaviours. Preventing pandemics at the source is the most equitable way to benefit all of humanity.
- Minimising human interactions with bats would involve restriction of activities in four main areas: bat hunting, consumption, and trade; bat guano harvesting, use, and trade; cave tourism; and incursions into key bat habitats with our livestock, homesteads, mines, and crop agriculture at smallholder and industrial scales (ie, deforestation).
- The ecosystem services that bats provide, from insect control to crop pollination, are enormous, and humans should not attempt to cull or harass bats (ie, activities that only serve to disperse them and increase the odds of zoonotic disease emergence for a range of reasons) but instead should leave them alone, while protecting them and the habitats that they need.

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all at a time when earnest collaboration even at local scales often seems elusive. However, stopping hunting, eating, and trading of bats; staying out of their caves; stopping deforesting and degrading of, or even starting to restore, their natural habitats; and stopping grazing livestock where bats live, will indisputably decrease the chances of another pandemic. Additionally, allowing bats to survive and thrive will have other benefits worldwide. The ecosystem services that bats provide, from insect control to crop pollination, are enormous. Humans should not attempt to cull or harass bats (ie, activities that only serve to disperse them and increase the odds of zoonotic disease emergence for a range of reasons)[7] but instead should leave them alone, while protecting them and the habitats that they need.

For more on the **International Union for Conservation of Nature Red List of Threatened Species** see https://www.iucnredlist.org

Perhaps the simplest thing that humans can do to lower pandemic risk, essentially immediately and at minimal cost, is to make harming or disturbing bats and their habitats a global taboo. Many taboos, such as those relating to dietary customs among different cultures, originally emanated from ecological or health concerns,[8] and adopting this taboo would undoubtedly be in humanity's best interest. Although there are other taxa of concern when it comes to pandemic risk, and although we note that practices around trade in live birds and mammals more broadly should be carefully addressed, bats are uniquely placed given what is already known about the wealth of zoonotic viruses that they harbour and the fact that, comparatively speaking, very few people around the world would suffer if bats were, for example, no longer consumed. The same cannot be said for every wildlife species that is consumed in different parts of the world,[9,10] particularly in terms of meeting the food security needs of people with low incomes who live in rural settings. So, although other taxa merit scrutiny, focusing on bats is possibly the simplest and most cost-effective step towards genuinely upstream pandemic prevention.

Bats as viral reservoirs

Bats are known reservoirs for a suite of viral pathogens, such as rabies virus (Rhabdoviridae family), Marburg virus (Filoviridae family), Hendra virus (Paramyxoviridae family), Nipah virus (Paramyxoviridae family), and MERS-CoV (Coronaviridae family), and bats of the Pteropodidae family are strongly believed to be a source of viruses of the genus *Ebolavirus*.[11–13] The role of bats in SARS-CoV and SARS-CoV-2 demands attention. Horseshoe (*Rhinolophus*) bats are probably the primary source of SARS-type coronaviruses, with such bats in Yunnan, China and Laos so far yielding the closest matches to SARS-CoV-2.[14–21] Even if SARS-like viruses might require an intermediate host before eventually getting to humans, that is no less reason to leave bats alone, keep them out of wildlife markets, avoid displacing them, and stop making incursions into their key habitats.

Bats are consistently shown to be highly important in studies that look at the chances and drivers of zoonotic disease spillover. Olival and colleagues[15] reported that bats harboured a significantly higher proportion of zoonotic viruses than other mammalian orders, and Johnson and colleagues[16] showed that primates and bats were significantly more likely to harbour zoonotic viruses than other orders. With more than 1400 species, bats are an incredibly diverse group of mammals,[22] which can make them seem over-represented as virus reservoirs.[23] Some researchers have suggested that the variations in the number of human-infecting viruses in a taxonomic order are explained by the number of species within that group, correlating with the total number of viruses in that group,[24] or by sampling bias.[25] But even given the allegations that bats are over-represented in virus hunting exercises, big gaps exist in data for bats as a group (ie, almost 20% of bat species do not have sufficient data for categorisation of their status on the International Union for Conservation of Nature Red List of Threatened Species),[26] suggesting that bats are probably still under-represented in field investigations and warrant further emerging infectious disease research.[16,27,28]

There is thus robust debate about whether bats are somehow unique in their ability to host viruses that pose risks to people, or whether the emphasis on them merely reflects their species diversity as a group or the amount of research effort focused on bats.[14–16,24,25] We do not take a side in that debate, but instead we emphasise that decisions need to be made on the basis of the information that is available at the time of the worst pandemic in generations if the next pandemic is to be prevented. We also note that ongoing anthropogenic alterations to Earth's natural systems, including but not limited to deforestation and climate change, will exacerbate the risks of bat-origin zoonotic pandemics.[29] Enough data exist to point to bats as a genuine hazard and to recognise the high virulence of some of the zoonotic viruses that they tend to host (ie, viruses that cause severe human disease);[30] mitigation of the associated risks is quite feasible by making changes in human behaviours. Additionally, the proposal to adopt a hazard analysis and critical control points approach for pandemic prevention by the One Health High-Level Expert Panel represents a framing that would support Chiroptera as a taxon of focus for upstream pandemic prevention efforts.[31]

Bats and the ecosystem services that they provide

Insectivorous bats consume various pests that harm agricultural crops and forests and cause disease. The numbers are staggering. A single colony of 150 big brown bats (*Eptesicus fuscus*) in IN, USA, eats about 1·3 million insects a year.[32] The US Department of Agriculture notes that a single small bat can eat up to 1000 insects in an hour.[33] These numbers can add up, with the colony of 20 million Mexican free-tailed bats (*Tadarida brasiliensis*) at Bracken Cave in San Antonio, TX, USA eating about 220 tons of insects every night. That amount translates into a massive number of crop pests consumed, increasing yields, reducing the need for costly pesticides, and thus helping rural livelihoods and economies. Insectivorous bats in Madagascar keep pests, such as paddy swarming armyworms and grass webworms, in check, which is vitally important for rice production in the country and the lives and livelihoods that depend on it.[34] Insect-eating bats not only control pests that harm crops but also prey on insects that can cause diseases in people. For example, many bat species consume mosquitoes, which can transmit the pathogens that cause malaria and a wide range of viral encephalitides.[35]

Bats also pollinate plants and disperse seeds, particularly in tropical and subtropical habitats. Bats pollinate more than 700 species of plants, many of which we use for food or medicine. Most of these plants are pollinated by two families of bats—ie, Megabats or Old World fruit bats (Pteropodidae) and New World leaf-nosed bats (Phyllostomidae)—which pollinate 528 different species.[36]

One notable example are agaves, which are pollinated by Mexican long-nosed bats (*Leptonycteris* spp). Agaves are ecologically important, because they help to stabilise the soil and prevent erosion, and economically important, because local communities use them for food, fences, fibre, and to produce mezcal (and thus tequila) and earn income from the tequila industry, which is economically significant. Many other valuable crop species rely on bats for survival. Bats pollinate more than 300 types of fruit, from peaches, bananas, and avocados to mangos and guavas, and they disperse the seeds of many others, such as figs and cacao.[36,37]

Seed dispersal by bats is especially important for tropical forest restoration efforts. The US Fish and Wildlife Service notes that seeds dispersed from bats can account for as much as 95% of early growth in recently cleared areas, such as in Amazonia.[38] Other studies focused on southern Mexico similarly concluded that bats are key for tropical reforestation due to their species diversity, abundance, and foraging habits, which translates into more seed dispersal—especially of pioneer plants—than that accomplished by birds.[39,40] Bats also help to disperse the seeds of plants that are crucial for soil fertility.[41]

The economic impact of the ecological services that bats provide is substantial, although still understudied. In North America alone, the pest control services that bats provide to the agricultural industry are estimated to be worth between US$3·7 and $53 billion a year.[32] Yet the US Geological Survey suggests that the real value is far greater, because that estimate considers only the economic impact on crops and neglects the value of bats eating disease-causing insects in forest ecosystems, which benefits the timber industry and the harvest of non-timber forest products, and economic activities that depend on bats as pollinators.[42] Ramírez-Fráncel and colleagues provide a useful global review of the important spectrum of ecosystem services that bats provide, including nutrient recycling.[43]

Applying the precautionary principle

As science writer David Quammen has noted, "Bat viruses *spill* into humans; they don't climb into us. They don't seek us out. And the spilling generally happens when we intrude upon bats in their habitats, excavating their guano for fertilizer, capturing them, killing them or transporting them live to markets, or otherwise initiating a disruptive interaction."[44] Disruptive interactions include deforestation, forest degradation (eg, via road-building), cave vandalism, and other activities that destroy or encroach on bat habitat, which in turn inevitably bring humans and bats into closer proximity.

Minimising interactions with bats would involve restriction of activities in four main areas: bat hunting, consumption, and trade; bat guano harvesting, use, and trade; cave tourism; and incursions into key bat habitats with livestock, homesteads, mines, and crop agriculture at smallholder and industrial scales (ie, deforestation). We discuss the rationale for focus on each of these four areas and provide a brief assessment of where these activities are taking place and the potential economic and social implications of restrictions.

Bat hunting, consumption, and trade

Hunting, consuming, and trading bats puts people in direct contact with the zoonotic pathogens that the animals might harbour, thus increasing the chance of spillover. "People who are involved in wildlife hunting, butchering and consumption risk transmission of infection from their close contact (eg, transcutaneous, mucosal routes) with live and dead animals or via contaminative routes (eg, faeces, fomites)", concludes a review of zoonotic infection risks from the wild meat trade in Malaysia.[45]

The same holds true along the supply chains for wildlife trade (whether such trade is legal or illegal, sustainable or unsustainable). Wild animal markets involve crowding of animals and mixing of species that usually do not naturally co-occur (ie, a diversity of wildlife from different places, livestock, and other domestic animals). This mixing, in turn, increases the opportunities for a virus to spill from one species to another, mutate, and evolve new and potentially dangerous traits. Additionally, inadequate sanitation increases the odds that people will pick up pathogens that are present or even acquire a novel pathogen that might subsequently cause a new human disease.

Restrictions on bat hunting, consumption, and trade would be feasible because of their seemingly small scale when compared with that of such activities involving other taxa. To our knowledge, two global reviews of bat consumption exist, both suggesting that bat hunting and consumption are not widespread. The reviews, one by Mildenstein and colleagues[46] published in 2016 and a 2009 survey by Mickleburgh and colleagues,[47] indicate that bat consumption is mostly locally based, tending to occur in specific locations within just a few countries.

According to these reviews, bat consumption tends to be most prevalent in southeast Asia, where bats are hunted in 10 of 11 countries.[46,47] Bat hunting and consumption appear to be most prevalent in Indonesia and the Philippines. Indonesia has a long history of consuming bats, and consumption is more commercialised than in other countries, with markets often selling many bat species. A study of the wildlife trade in Sulawesi, Indonesia examined bat hunting and trade there, and estimated that between approximately 660 000 and more than 1 million flying foxes (*Pteropus* spp) were traded in Sulawesi, and that offtake rates were unsustainable.[48] In the Philippines, laws restrict bat hunting, but Mildenstein and colleagues noted that the lack of enforcement allows people to continue, so hunting activity is still high but is mostly for personal or local use rather than for sale.[46]

Other places with notable bat hunting and consumption include southern China (but not the rest of China), some of the Pacific Islands (eg, Vanuatu, Federated States of Micronesia, and Fiji), and parts of Bangladesh.[46] Bat hunting also occurs in parts of west and central Africa. In Ghana, for example, offtake of African straw-coloured fruit bats (*Eidolon helvum*) was estimated to be at least 128 000 bats a year in a 2011 study, with the bats sold in markets and restaurants and kept by hunters for personal consumption.[49] Another investigation of human–bat interactions in rural Ghana conducted in 2011–12 reported that, of roughly 1274 survey respondents in three villages, 581 (45·6%) reported bat consumption.[50] Of those 581 consumers, 237 (40·8%) obtained bats from caves, 123 (21·2%) caught bats on farms with bat roosts, 114 (19·6%) bought bats from local markets, and 60 (10·3%) bought bats at restaurants. As shown by these studies, often much of the underlying data documenting the practice of bat consumption in African countries (eg, Benin, Ghana, Guinea, Liberia, and Nigeria) come from studies that were conducted more than a decade ago, and thus the situation might have changed.

Generally, there is little to no bat consumption in much of North or South America, southern and east Africa, and most of China, although e-commerce in bat specimens as souvenirs and taxidermy specimens should be noted.[51] Even where bat hunting and consumption are prevalent, it seems that their nutritional importance to meeting overall dietary needs is still minimal. Mildenstein and colleagues note that “In areas where bats are eaten, they are rarely the only available source of protein”, with exceptions for times of food insecurity, such as natural disasters.[46]

Bat hunting is usually, but not always, for local consumption rather than a way to earn income. Although much has been written about the wildlife and bushmeat trade, there are few specifics about the volume and economic importance of bats within that trade. Indeed, Coad and colleagues note that, in much of the voluminous literature on wild meat hunting and consumption, bats are rarely mentioned and documented. It is unclear whether this data gap is due to insufficient research or because bat hunting and consumption are, comparatively speaking, not that important in the wider context of bushmeat use.[52]

An analysis of bushmeat hunting and trade in Myanmar identified that, even though people did hunt bats, their preference for them was extremely low. They far preferred to hunt dozens of other types of animals, including primates (eg, Phayer’s langur), rodents (eg, lesser bamboo rats), carnivores (eg, palm civets), reptiles (eg, monitor lizards), and ungulates (eg, serow).[53]

Although most studies examine the hunting of bats for food, bats are also hunted for medicinal use. A literature review of medicinal uses of bats reported that such use was geographically widespread, with mentions of it occurring in 37 countries, most commonly to treat asthma.[54] While consumption of bats for food was most prevalent in Asia, Africa, and Oceania, medicinal use of bats occurred most in south Asia and southeast Asia. But perceptions on the medicinal use of bats might be changing, with social media in places such as Indonesia promoting inhalers because of the ineffectiveness of bats to treat asthma.[54]

There is still much to learn about bat hunting, consumption, and trade, but the relative paucity of detailed information despite ongoing and extensive research on the bushmeat trade suggests that demand for bats is not widespread and that they are not nutritionally or economically crucial, making potential restrictions and prohibitions in the interests of local and global public health perhaps easier to implement. The global community should now collaborate to limit hunting, consumption, and trade activities as a priority.

Guano harvesting, use, and trade

Bat guano, or the faeces of bats, has been used as a natural fertiliser for agriculture for hundreds of years. In the 1600s, it was so valuable to the Incas in Peru that they instituted a death penalty for harming the bats that produced it.[55] Bat guano is often considered to be superior to other fertilisers. Because of its high nitrogen, phosphorus, and potassium content, it not only helps plants to grow but also supports larger yields. Typically, bat guano is a preferred alternative to chemical fertilisers because it gets better results in terms of productivity, is less costly, and is seen as causing less harm to the environment.

Bat guano is collected from caves where large numbers of bats roost, and both bats and guano play integral roles in the cave ecosystem. Unlike other environments, caves have near constant humidity and temperature, so that minor disturbances can affect all that lives there. In their study on the ecological and economic importance of bat guano, Sakoui and colleagues explain that bat guano provides organic material to the cave environment and hosts various specially adapted organisms, including bacteria, fungi, and insects.[56] Furthermore, the decomposition of guano acts as a source of heat and humidity, as do the bats themselves.

Data are scarce on the global scale of bat guano collection and its value, with most studies focused on specific caves at particular points in time. For example, in Cambodia, Furey and colleagues estimated that annual guano harvests at Ta Rumm #1 cave ranged from 41 to 71 tons over the study period in 2011–17.[57] At Bracken Cave in San Antonio, TX, USA, where Mexican free-tailed bat guano has been harvested since the late 1800s, an automated vacuum-type system now collects about 92 tons of bat guano over a 21-day season each year.[55] Retail prices for the tons of fertiliser produced from the guano from Bracken Cave have ranged from \$2·86 to \$12·10 per kg (yielding \$239 000 to \$1 million per year).[58] In Myanmar, a single cave (with about 200 000 bats) on Sudaung mountain yielded 36 tons of guano each year, selling for about \$0·36 per kg (earning a total of almost \$13 000),[59] and elsewhere in Myanmar five sites with 1·7 million bats yielded 120 tons of guano annually, earning about \$21 500 each year for the 28 people working there.[60]

Studies of bat guano and disease consistently suggest that spending time in bat roosting caves increases potential exposure to pathogens. Bat guano from a cave in Ratchaburi Province, Thailand, harvested for sale as agricultural fertiliser, tested positive for the subgenus *Merbecovirus* (ie, the lineage that includes MERS-CoV), and the researchers noted that guano miners face considerable health risks because of the chance of direct contact with bat-borne pathogens.[61] In northern Laos, viruses from the subgenus *Sarbecovirus* that were deemed to be potentially zoonotic were found to circulate in cave bats, with guano miners and other cave visitors at potential risk.[19] Similarly, bat guano from Linno Cave in Myanmar contained six previously unknown coronaviruses,[62] and in southern Viet Nam, researchers identified six known coronaviruses in bats, clustered in three Coronaviridae genera (ie, *Alphacoronavirus*, *Betacoronavirus*, and *Gammacoronavirus*), at bat guano farms and roosts near human dwellings.[63]

Scientists are re-examining a well known case of guano collectors and presumed histoplasmosis. In April, 2012, six people became severely ill, with three dying, after removing bat faeces from Mojiang mine in Yunnan province in southwest China. At the time, scientists believed that these people had histoplasmosis from inhaling fungal spores in the droppings. But some people now suggest that these cases could provide clues to the origin of SARS-CoV-2 and should be studied.[64]

Cave-roosting bats are especially vulnerable to human disturbance during crucial reproductive periods, such as late pregnancy, lactation, and weaning.[57] Guano extraction can require modifications of cave entrances or chambers, loud noises, and bright lights and can cause changes in air temperature and humidity, all of which can prompt females to drop their pups or wake up hibernating bats and force them to increase their metabolic rates at a time when they cannot afford to do so.[65]

Several sets of guidelines have been developed to prevent harm to bats, with an emphasis on making guano harvesting safer for bats and the workers. These guidelines recommend that people should not be near the bats, harvesting should take place at night when bats are not in the cave, and workers should wear personal protective equipment, such as masks (or, better yet, respirators) and gloves.[66,67]

Although there is still much to learn about guano collection, it seems that conditions are ideal to shift this industry in ways that protect both bats and people. Already, some communities restrict the times when guano can be harvested to protect bats, or they limit access to bat roosting caves. There are several basic, cost-effective ways for this industry to reduce the human interface with potential zoonotic pathogens. We should be implementing these methods as a priority and rethinking guano use altogether, whether the source is caves or artificial roosts[63] built for guano farming.

Cave tourism

Caves all over the world attract thousands of tourists every year. In the mid-1990s, around 20 million people worldwide visited caves recreationally each year, and these numbers have increased, especially in east Asia.[65] A 2013 study estimated that cave tourism contributes about \$100 million annually to the global economy and that the approximately 500 major show caves worldwide (ie, a cave for which a fee is paid to visit) host about 250 million visitors yearly.[68]

Cave tourism can bring direct benefits to local communities but can also bring disruptions. For instance, an examination of cave tourism at Agu-Owuru Cave in Nigeria noted both positive effects, such as income gained from access fees, and negative effects on the host community, such as visitors disrespecting the cave and its local religious significance and detrimental effects on the delicate environment of the cave.[69]

As noted, caves themselves are fragile ecosystems, and tourism has the potential to harm them. Several studies in diverse locations, such as China, Canada, Madagascar, and Turkey, have looked at the effects of cave tourism on bats. When caves are developed for tourism, physical modifications, such as stairs or walkways, and artificial lighting, can disturb or destroy the environment, as was noted for guano harvesting operations. Cave visitors, too, can change the cave environment by causing fluctuations in the cave temperature, humidity, and carbon dioxide concentrations, which in turn can prompt bats to abandon their roosts.

Cave tourism brings many people into what used to be a hidden and remote habitat, thus increasing contact between people and bats (or their excrement and bodily fluids), with concomitant opportunities for viral spillover. It is important to always keep in mind that, once a dangerous virus spills over into people, people can potentially quickly and easily transmit the virus worldwide, as was clearly shown with SARS-CoV-2.

Search strategy and selection criteria

We started our literature search with a focus on human interactions with bats and the places they live, in terms of whether the bat–human interface might pose substantial risks of greater public health concern than human interactions with other groups of animals that can also carry zoonotic pathogens of serious concern (eg, rats, primates, and birds). We searched Google Scholar, Google, and Cornell University's digital library resources for papers published between Jan 1, 1990 and Nov 30, 2022 using the search terms "bat" and "virus", "reservoir", "spillover", "pandemic", or "zoonotic". We then continued our literature review, searching for papers published between these dates using the search terms "bat" and "ecosystem services" or "pollination"; "bat" and "hunting", "consumption", "trade", or "nutrition"; "guano" and "harvest", "use", or "trade"; and "bat" and "cave tourism". We included papers published in English that provided credible, useful information for analysis. Papers of interest were selected by three researchers (SAO, LAN, and HLL). We also evaluated reports written by One Health experts for multilateral agencies, such as WHO, that were recommendations for preventing the next pandemic.
We conducted interviews to compile expert opinions from scientists involved in research on bats and their relation to viral spillovers; ecosystem services; hunting, consumption, and trade; guano harvesting, use, and trade; and cave tourism. We compiled a list of 60 experts on the basis of our knowledge of the fields and the publications and reports from our literature search. We categorised the experts into basic thematic areas: bats and viral spillovers; bat hunting, consumption, and trade; guano harvesting, use, and trade; and cave tourism, with some experts overlapping between the different thematic areas. We conducted 1 h informal interviews with 11 experts from the list of 60 people to cover the different themes of interest.

Notably, the risk of disease can work both ways. In late March, 2020, the US Fish and Wildlife Service issued an advisory asking bat biologists to suspend fieldwork due to concerns that the SARS-CoV-2 virus could spill back from humans to bats.[70] And previously, in North America, caving restrictions were put in place to mitigate the risk of ongoing White-nose fungus (*Pseudogymnoascus destructans*) dissemination, which has devasted North American bat populations since it was first detected in bats in NY, USA in 2006–07, having been introduced from Eurasia.

Measures to restrict or at least regulate cave tourism can reduce disturbance of bats while mitigating zoonotic spillover risks. These measures can include restricting cave visits by recreational users or changing the seasonal or daily timing of visits to avoid times when bats are vulnerable. Parts of caves that are close to the bat colonies could also be closed, and personal protective equipment could be routinely used.[71,72]

One possibility is to continue to encourage bat tourism, but rather than focus on cave tourism, switch to bat viewing. One highly successful initiative is centred on the Congress Avenue Bridge in Austin, TX, USA, which brings about 140 000 visitors a year to downtown Austin during the annual period when the nightly emergence of 1·5 million Mexican free-tailed bats can be viewed and generates an estimated $3 million annually.[73]

Deforestation

Deforestation and other land-use changes can increase the chances of viral spillover by putting people and livestock in regular close proximity to canopy-roosting bats and their bodily fluids and excrement. One well known concern is Hendra virus, which when passed from bats causes respiratory and neurological disease with high mortality rates in horses and then people. First discovered in 1994 in Hendra, QLD, Australia, viral spillover most likely occurred when horses ate grass sprinkled with virus-laden bat faeces from under a fig tree where *Pteropus* fruit bats (also known as flying foxes) had fed. With expansion of human settlements and agriculture into their habitat, bats often stayed in or were attracted to the area, with fruit trees in paddocks providing ready food.[74,75] Imagine if SARS-CoV-2 had mortality rates of more than 50%, akin to Hendra virus. Thus far, no human-to-human transmission of Hendra virus has been observed.[76]

Similarly, deforestation has also affected Nipah virus spillover in Bangladesh. There, changes in forest cover have led to bats now roosting in and being attracted to areas of high human population, where bats opportunistically feed on food sources also used by people and contaminate them with their excreta or saliva.[77,78] Nipah virus outbreaks were first identified in Malaysia in the late 1990s, where pigs raised under fruit trees that *Pteropus* bats sought out became intermediate hosts, infecting farmers and slaughterhouse workers.[77]

Additionally, land conversion stresses bats and other wildlife, which can reduce their resistance to viruses and increase their viral shedding.[79,80] In turn, these processes can increase the opportunities for spillover and spread in people, what Plowright and colleagues call the infect–shed–spill–spread cascade.[81]

Conclusion

The majority of emerging viruses come from wildlife[82]—but it is important not to blame wildlife or to create a backlash against wild animals. In fact, we argue for the opposite: the problem is humans and their practices and actions. What is desperately needed could perhaps best be described as behavioural distancing, not to be confused with the physical distancing that was encouraged during the COVID-19 pandemic, but just as important over the longer term. Although hundreds of thousands of viruses exist in mammals alone, there are really only three basic ways that humans exacerbate the risk of getting infected: eating the body parts of wild animals, capturing and mixing wild species together in markets for sale, and encroaching on and usually destroying what is left of wild nature at a rapid pace, all greatly enhancing encounter rates with new and potentially dangerous pathogens along the way. Humans simply cannot continue to pillage what is left of wild nature and fellow species on this planet and hope to see no more pandemics.[83] A change of course is urgently required.

Similar to the SARS-CoV outbreak of 2003, SARS-CoV-2 can be traced back to a bat virus. Whether someone handled or ate an infected bat, was exposed to a bat's bodily fluids in some other way, or was exposed to another animal that had been infected by a bat will quite likely never be known for sure. But not all of the details are needed to act.

Markets that sell wildlife for human consumption often feature domestic and wild animal species—eg, in large commercial markets, a mix of animals from the land and sea from many locations is often present—all crowded together, along with the pathogens that they carry. Many, if not most, of the free ranging wildlife-related supply chains feeding these markets are illegal, and many are leading to the extinction of a wide range of wildlife species that are in high culinary or cultural demand. But viruses do not care whether a host animal is obtained legally or sustainably. For decades, the conservation community has tried extremely hard to stop this trade, without success; national and global leaders never seemed to feel that the costs to global biodiversity mattered all that much.

Society should now ask, what is the least that can be done to mitigate the risks of future pandemics, to prevent worldwide surges in human deaths, illness, and suffering—and more waves of multitrillion dollar impacts on the global economy. The issues around consumption and trading of wildlife are diverse and complex, with many people living in rural settings being dependent on wild meat for their nutritional needs. But bats might be one taxonomic group that humanity can successfully take a step back from, with minimal costs or inconvenience to the vast majority of the 8 billion people on Earth, respecting the order Chiroptera for all that these species contribute through the range of extremely valuable ecosystem services that they provide. We do not suggest that those people and places that would potentially be asked to modify activities, with concomitant livelihood impacts, should not be consulted and assisted by the broader global community that stands to benefit from any such behavioural changes that lessen human–bat interactions. Given that most, but not all, of the identified bat-related activities of concern occur in low-income and middle-income countries, it is logical from an equity perspective to co-design ways to try to mitigate any socioeconomic or cultural burdens that voluntary changes in behaviour would cause and for wealthier countries to provide assistance through negotiated, logical forms of compensation. Such compensation would undoubtedly be a small price to pay to lessen the risk of future pandemics.

The global community missed its chance to stop SARS-CoV and SARS-CoV-2 from emerging—how many more times will humanity allow this cycle to repeat? How long will governments ignore the science that is in front of them? It is past time for basic, pragmatic action. A global taboo is needed, whereby humanity agrees to leave bats alone, not fear them or try to chase them away or cull them, but to let them have the habitats they need and live undisturbed by humans.

We cannot put a figure on how much risk would be mitigated by such a change in human behaviour, but preventing pandemics at the source is the most equitable way to benefit all of humanity. Given what is known, leaving bats alone would definitely reduce the risk of another zoonotic pandemic. As others have pointed out, no one intervention will prevent the next pandemic.[2] But focusing resources solely on efforts to address pandemics once they have already been unleashed, as most so-called prevention plans currently do, naively ignores the fact that humanity's broken relationship with wild nature is how things got to this point in the first place.

Contributors
SAO conceptualised, designed, and acquired funding for the study with support from HLL. LAN, SAO, and HLL conducted literature searches and interviews and reviewed, analysed, and interpreted the information collected. HLL curated the data from literature reviews and interviews. LAN and SAO wrote the initial draft with contributions from HLL. SL and CW provided technical input on the manuscript, assisting with reviewing and editing. All authors approved the final version.

Declaration of interests
We declare no competing interests.

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