IN THE HIGH COURT OF MANIPUR

AT IMPHAL

PIL No. 21 of 2020

The Manipur Valley Village Reserve Forest Rights Protection Association represented by its President Shri Angom Tomba, aged about 58 years, S/o A. Nilachandra, resident of Phayeng Kangchup Chingkhong P.O. & P.S. Lamsang, District, Imphal West, Manipur- 795146.

... Petitioner.

1. The State of Manipur through the Additional Chief Secretary (Forest), Govt. of Manipur, Secretariat North Block, P.O. P.S. Imphal, District, Imphal West, Manipur- 795001.
2. The Commissioner (Hills), Govt. of Manipur, Secretariat North Block, P.O., P.S. Imphal, District, Imphal West, Manipur-795001.
3. The Commissioner (Revenue), Govt. of Manipur, Secretariat South Block, P.O., P.S. Imphal, District, Imphal West, Manipur-795001.
4. The Principal Chief Conservator of Forest (HoFF), Govt. of Manipur, Sanjenthong, P.O. & P.S. Porompat, District, Imphal East, Manipur-795005.
5. The Director of Settlement and Land Records, Govt. of Manipur, Lamphelpat. P.O. & P.S. Imphal, District, Imphal West, Manipur-795001.
6. The Union of India represented by the Secretary to the Ministry of Environment, Forest and Climate Control, Indira Paryavaran Bhavan, Jor Bhag Road, New Delhi – 110 003.

... Respondents.

B E F O R E
HON'BLE THE CHIEF JUSTICE SHRI RAMALINGAM SUDHAKAR
HON'BLE MR. JUSTICE A. BIMOL SINGH

For the petitioner	::	Mr. Kh. Tarunkumar, Advocate
For the respondents	::	Mr. Lenin Hijam, Advocate
		Mr. S. Suresh, ASG
Date of Order	::	03.06.2020

Ramalingam Sudhakar, C.J.

[1] Heard Mr. Kh. Tarunkumar, learned counsel appearing for the petitioner, Mr. Lenin, learned Additional Advocate General appearing for the State respondents and Mr. S. Suresh, learned ASG.

[2] The Public Interest Litigation was admitted on 27.05.2020 on the following grounds.

> *"[3] The present PIL focuses on a very important issue of Forest and reserved forests of Manipur being denuded and illegally encroached for various activities, the details of which have been highlighted in the present PIL in the representation dated 15.6.2019, Annexure-A/12, Page 67 to the Hon'ble Chief Minister of Manipur and the representation dated 20.9.2019, Annexure-A/14, Page 70 addressed to the Hon'ble Prime Minister of India.*
>
> *[4] A detailed order will be issued shortly. However to ensure that the respondents authorities are made aware of the nature of present public interest litigation and the important issue that is required to be adjudicated, we direct that the Union of India represented by the Secretary to the Ministry of Environment, Forest & Climate Control be added as respondent No.6 in the present PIL.*
>
> *[5] Issue notice to all the respondents. Mr. Lenin Hijam, learned Addl.AG accepts notice for all the respondents No.1 to 5.*
>
> *[6] Copies of the petition to be handed over by Mr. Kh. Tarunkumar to Mr. Lenin Hijam, learned Addl.AG so that he can pass it over to the respondents No.1 to 5. In the same manner, Mr. Tarunkumar will serve a copy of the petition with annexures to Mr. S. Suresh, learned ASG who will appear for the newly impleaded respondent No.6.*
>
> *[7] List again on 03.6.2020 for passing a detailed order."*

[3] When the matter was heard today, the learned counsel for the petitioner referred to a publication by the Government of Manipur titled "Reserved Forests and Protected Forests of Manipur". It contains the details of Reserved and Protected Forests of Manipur, the map and locations, area and the nature of forests, the flora and fauna of Manipur relatable to the forest. The list of Reserved Forests and Protected Forests of Manipur is annexed as **Annexure-A** to this order.

[4] The petitioner's association, represented by its President which has filed this Public interest Litigation, is a responsible citizen striving to protect and improve the natural environment including forests, lakes, rivers and wild life to discharge these fundamental duties set out in Part IV-A, Article 51-A. Art.51-A (g) of the Constitution of India reads as follows :

> ***51-A. Fundamental duties****. – It shall be the duty of every citizen of India –*
>
> *(g) to protect and improve the natural environment including forests, lakes, rivers and wild life, and to have compassion for living creatures;*

Considering the important issue raised, the following order is passed.

[5] "A virus is a piece of bad news wrapped in protein", said, Nobel Laureate Sir Peter Medawar, an eminent biologist. That simple looking protein coated RNA is rocking the world to pieces. "Is there a link between destruction of forest and pandemic ?" is a question that is posed before this Court .

[6] The COVID-19 has crossed the great walls and trampled continents crossing over mighty oceans to decimate the homo sapiens young and old, able and feeble, and with no distinction as to class or creed like the march of the Macedonian army in its quest to reach the edge of the planet. The year 2020 is witnessing a great purge while the planet is encircled by an invisible RNA, a code which all, the best of mankind is trying to decode. Humanity is facing the gravest of pandemic and exploring all means to stay afloat physically, mentally and economically. While the whole of the humanity prays for this tide to quell the quest for change in every aspect of life has become inevitable.

[7] Charles Darwin, Naturalist and author said this :-

"It is not the strongest of the species that survive, nor the most intelligent, but the one most responsive to change"

In change, from a zoonotic virus to a human host infected virus, the pandemic, COVID-19 has proved that it can survive beyond humanity. We, however, are caught on the wrong side and frantically trying to survive pouring over science and medicine to tackle the pandemic and to find a vaccine to save humanity for the present and the future. While the immediate focus is on finding a wonder drug, an elixir to save human beings, the need to probe and unravel the mystery behind nature's fury in this pandemic is a test to human intellect. It is time for the collective wisdom of human beings to reflect where we went wrong or what went awry and what should be done. There are number of theories that abound as we traverse through the views of scientists, doctors, researchers, scholars, expressed in their scientific literature. There are very many reasons attributed for the present pandemic which evidently is a sequel, with many more to come in the times to come. Amidst all the cause and effect theories that propounded, there appears to be one significant factor which needs the world's attention - irrespective of anyone nation being the cause for the current pandemic -that is desecration of "Nature" and environment.

[8] Environmental degradation has taken many ugly forms and it is being seriously discussed by comity of nations in several global and national level colloquiums. There are protocols and to name a few :-

List of conventions:

1. Convention on the International Trade in Endangered Species of Wild Flora and Fauna (CITES), Washington DC-1973
2. Convention on Nature Protection and Wild Life Preservation in the Western Hemisphere – Washington DC, 1940
3. Convention on Biological Diversity (CBD), Nairobi, 1992
4. Kyoto Protocol
5. Cartagena Protocol on Biosafety, 2000

[9] Despite the best efforts taken, the decline of nature in many ways is worse than the cure suggested. All the environmental protection laws of different countries inter alia, attempt to save the earth by controlling pollution of air, water and earth. The systematic and constant degradation of atmosphere and stratosphere, the forests, the rivers, the mountains, the glaciers, the deserts and the mighty oceans are posing a great challenge. The scientific study shows a bleak future over the years, however, it is no time to lose hope, nor our focus in saving the planet from self-destruction due to human exploitation.

[10] The Covid-19 is stated to have passed over from a wild animal/mammalian host into human beings. There are many versions to the pandemic but in the present case we touch upon one specific aspect that appears to have a definitive correlation to the spread of virus form forest dwelling wild life to human beings. In the year 2016, Jim Robbins, a veteran journalist highlighted the impact of deforestation and disease in his Article **"How Forest Loss Is Leading to a Rise in Human Disease"** [**Yale environment 360** – Feb 23rd 2016].

[11] He cites one example referring to the cutting down of the world's oldest tropical forest in Borneo island for growing palm for oil as one of the reason for the wiping out of the Indonesia/Malaysia forests high in biodiversity, which affected the wild life habitat, resulting in spread of life threatening diseases such as malaria and dengue fever (Journal of Emerging Infectious Diseases). One particular instance quoted by the author will be of great relevance.

> *"This form of the disease was once found mainly in primates called macaques, and scientists from the London School of Tropical Medicine and Hygiene wondered why there was a sudden spike in human cases. Studying satellite maps of where forest was being cut down and where it was left standing, the researchers compared the patchwork to the locations of recent malaria outbreaks. They realized the primates were concentrating in the remaining fragments of forest habitat, possibly increasing disease transmission among their own populations. Then, as humans worked on the new palm plantations, near the recently created forest edges, mosquitoes that thrived in this new habitat carried the disease from macaques to people.*[1]
>
> *Such phenomena are not uncommon. "In years when there is a lot of land clearance you get a spike in leptospirosis [a potentially fatal bacterial disease] cases, and in malaria and dengue," says Peter Daszak, the president of Ecohealth Alliance, which is part of a global effort to understand and ameliorate these dynamics. "Deforestation creates ideal habitat for some diseases."* [2]
>
> *The Borneo malaria study is the latest piece of a growing body of scientific evidence showing how cutting down large swaths of forests is a major factor in a serious human health problem — the outbreak of some of the world's most serious infectious diseases that emerge from wildlife and insects in forests. Some 60 percent of the diseases that affect people spend part of their life cycle in wild and domestic animals*.[3]
>
> *The research work is urgent — land development is rapidly taking place across regions with high biodiversity, and the greater the number of species, the greater the number of diseases, scientists say. They are deeply concerned that the next global pandemic could come out of the forest and spread quickly around the world, as was*

1-3: **"How Forest Loss is Leading to a Rise in Human Disease" by Jim Robbins** *the case with SARS and Ebola, which both emerged from wild animals.*

***Mosquitoes are not the only carriers of pathogens from the wild to humans. Bats, primates, and even snails can carry disease, and transmission dynamics change for all of these species following forest clearing, often creating a much greater threat to people**."*[4]

(Emphasis supplied)

[12] The adverse impact of deforestation for agriculture purpose was highlighted in the following manner :-

"Throughout human history pathogens have emerged from forests. The Zika virus, for example, which is believed to be causing microencephaly, or smaller than normal heads, in newborns in Latin America, emerged from the Zika forest of Uganda in the 1940s. Dengue, Chikungunya, yellow fever, and some other mosquito-borne pathogens likely also came out of the forests of Africa.[5]

Forests contain numerous pathogens that have been passed back and forth between mosquitoes and mammals for ages. Because they evolved together, these viruses often cause few or no symptoms in their hosts, providing "a protective effect from a homegrown infection," says Richard Pollack of the T.H. Chan School Public Health at Harvard. ***But humans often have no such protection.***[6]

The cascade of human-induced ecological changes dramatically reduces mosquito diversity. "The species that survive and become dominant, for reasons that are not well understood, almost always transmit malaria better than the species that had been most abundant in the intact forests," write Eric Chivian and Aaron Bernstein, public health experts at Harvard Medical School, in their book How Our Health Depends on Biodiversity. "This has been observed essentially everywhere malaria occurs."[7]

(Emphasis supplied)

[13] While the article focuses on prevalence of mosquito borne disease due to deforestation, the same analogy applies to virus as we can decipher from recent scientific research on this aspect.

"In the forest, we found almost no breeding whatsoever, and no biting by the adult mosquitoes," Vittor said. That's probably because the ecology of the deforested landscape — short vegetation and deep water — favored their breeding, and they need human blood to grow their eggs.[8]

4-8: "How Forest Loss is Leading to a Rise in Human Disease" by Jim Robbins

The types of mosquitoes that do well in this radically altered ecosystem are more "vector competent," which means their systems are particularly good at manufacturing a lot of the pathogen that causes malaria. A study in Brazil, published in the Journal of Emerging Infectious Diseases in 2010, found that clearing four percent of the forest resulted in a nearly 50-percent increase in human malaria cases. [9]

The ecology of the viruses in deforested areas is different. As forests are cut down, numerous new boundaries, or edges, are created between deforested areas and forest. A mosquito called Aedes africanus, a host of the yellow fever and Chikungaya viruses, often lives in this edge habitat and bites people working or living nearby. Other primates, which are also reservoirs for the pathogens, gather in the borders of these different ecosystems, providing an ongoing source of virus for the insects." [10]

[14] The impact of such pandemic on civilization from time immemorial has been explained as by the author as under:-

"Scientists are concerned that these outbreaks exacerbated by human alteration of landscapes could cause the next pandemic. The Roman Empire once stretched from Scotland to Africa and lasted for more than 400 years. No one knows exactly why the empire collapsed, but one contributing factor may have been malaria. A mass grave of babies from that era, excavated in the 1990s, found, through DNA analysis, that many of them had died from malaria, according to a study published in 2001 in the journal Ancient Biomolecules. Some researchers speculate that the malaria outbreak may have been exacerbated by deforestation in Rome's surrounding Tiber River Valley to supply timber to the growing city." [11]

[15] The article clearly spells out and is interesting to note in the present scenario the path that a pathogen will take when it comes out of the forest :-

"Once a disease has left a forested region, it can travel in human beings, crossing the world in a matter of hours by airplane before the person even shows symptoms. How well it does in its new homes depends on several factors. Once Zika travelled to Brazil from Africa, for example, it flourished because Aedes aegypti mosquitoes hang out around people and love to lay their eggs in small containers of water. Many people in Brazil's large slums store water in buckets, and standing water also collects in tarps, old tires, and trash. [12]

Mosquitoes aren't the only creatures that bring fever out of the forest. Angolan freetailed bats were believed to harbor the Ebola virus that broke out and killed more than 11,000 people last year. And AIDS, which has killed more than 25 million people worldwide, came from people eating bush meat, likely chimpanzees." [13]

9-13: "How Forest Loss is Leading to a Rise in Human Disease" by Jim Robbins

[16] The safe and real solution suggested in the article is protection of forest and its wild life. The scientific paper along with numerous other scientific data will establish that deforestation is a very serious issue akin to opening the Pandora's Box and resultant disease manifestation.

> *"Part of the solution is to recognize and understand these connections and teach people that keeping nature intact has protective effects. And where people do cut down forests or build roads, numerous steps can be taken to lessen the chance of mosquito-borne disease outbreaks — education campaigns, more clinics, health training, and medical monitoring.*[14]
>
> *Another piece of the puzzle is to know what pathogens the world might be up against in the future as they come out of the forest. Ecohealth Alliance is cataloguing wildlife borne viruses in wild places where there is new encroachment into undisturbed nature and health care is poor or non-existent. The goal is to better understand how these viruses might spread and to potentially develop vaccines.*
>
> *"If we could deal with the trade in wildlife and deforestation we wouldn't need to stop an outbreak," like Zika or Ebola, said Daszak, the organization's president. "We would have already dealt with it."* [15]

[17] To lay emphasis on the need to protect forest and disconnect the emergence of infectious disease to humans, we are inspired by the article, **"Forest and emerging infectious diseases of humans"** written by Bruce A. Wilcox and Brett Ellis, of Centre for Infectious disease Ecology in Asia Pacific Institute for tropical medicine and infectious disease, University of Hawaii, at Manoa, USA.

> *"The first plague-causing pathogens such as smallpox are believed to have originated in tropical Asia early in the history of animal husbandry and large-scale forest clearing for permanent cropland and human settlements (McNeil, 1976). Crowding and the mixing of people, domestic animals and wildlife, along with a warm humid climate, were as ideal for pathogen evolution, survival and transmission several millennia ago as they are now.*[16]
>
> *The concept of emerging infectious diseases (EIDs) was prompted by the appearance of novel pathogens such as human immunodeficiency virus (HIV) and Ebola virus; the evolution of more*

14-15: **"How Forest Loss is Leading to a Rise in Human Disease" by Jim Robbins**

16: **"Forests and emerging infectious disease of humans" by: Bruce A. Wilcox and Brett Ellis**

virulent or drug-resistant pathogenic variants of known microbes; and the geographic expansion and increasing epidemic outbreaks of the diseases caused by these pathogens as well as older diseases such as malaria and dengue. More recently, the concept was reinforced by the dramatic outbreak of severe acute respiratory syndrome (SARS) virus. [17]

An increasing number of studies on EIDs point to changes in land cover and land use, including forest cover change (particularly deforestation and forest fragmentation) along with urbanization and agricultural intensification, as major factors contributing to the surge in infectious diseases. Indeed the current increase coincides with accelerating rates of tropical deforestation in the past several decades. Today, both deforestation and emerging infectious diseases remain largely associated with tropical regions but have impacts that extend globally. Both are similarly intertwined with issues of economic development, land use and governance, requiring cross-sectoral solutions."[18]

[18] To emphasize with scientific data on the outburst of EIDs due to deforestation, the article gives a list of Forest associated emerging infectious disease.

"This article provides an overview of the role of forests and deforestation in EIDs. It highlights the most prominent forest-associated diseases and briefly describes the current state of understanding of the mechanisms by which forest conversion and alteration contribute to EIDs. Finally, it identifies forest resource management measures required to mitigate the EID problem. Expansion into the forest, involving more frequent contact with wildlife, exposes humans to pathogens that are foreign to them and is a frequent cause of disease outbreaks – for example yellow fever in the case of this forest-adjacent settlement in Kenya"[19]

Examples of forest-associated emerging infectious diseases

Agent/disease	Distribution	Hosts and/or reservoirs	Exposure	Possible emergence mechanisms
Viruses				
Yellow fever	Africa South America	Non-human primates	Vector	Deforestation and expansion of settlements along forest edges Hunting Water and wood collection Domestication of vectors and pathogen

Dengue	Pantropical	Non-human primates	Vector	Mosquito vector and pathogen adaptation Urbanization and ineffective vector control programmes
Chikungunya	Africa Indian Ocean Southeast Asia	Non-human primates	Vector	Pathogen and vector domestication
Oropouche	South America	Non-human primates Others	Vector	Forest travel Vector composition changes
SIV	Pantropical	Non-human primates	Direct	Deforestation and human expansion into forest Hunting and butchering of forest wildlife Pathogen adaptation
Ebola	Africa	Non-human primates Bats	Direct	Hunting and butchering Logging Outbreaks along forest fringes Agriculture Alteration of natural fauna
Nipah virus	South Asia	Bats Pigs	Direct	Pig and fruit production on forest border
SARS	Southeast Asia	Bats Civets	Direct	Harvesting, marketing and mixing of bats and civet cats Wildlife trade for human consumption
Rabies	Worldwide	Canines Bats Other wildlife	Direct	Human expansion into forest
Rocky Mountain spotted fever	North America	Invertebrate ticks	Vector	Human expansion into forest Forest recreation

Protozoa				
Malaria	Africa Southeast Asia South America	Non-human primates	Vector	Deforestation, habitat alteration beneficial for mosquito breeding Human expansion into forest, non-human primate malaria among humans
Leishmaniasis	South America	Numerous mammals	Vector	Human expansion into forest Domestication of zoophilic vectors Habitat alteration, habitation building near forest edge Deforestation Domestication of zoonotic cycles by non-immune workers
Sleeping sickness	West and Central Africa	Humans	Vector	Human expansion into forest, disease incidence associated with forest edge
Bacteria				
Babesiosis	North America Europe	Humans W ildlife	Vector	Disease often found among ticks in forested areas
Lyme disease	Worldwide	Humans Deer Mice	Vector	Possible association with deforestation and habitat fragmentation Forest workers at increased risk of disease
Leptospirosis	Worldwide	Rodents	Indirect	Watershed alteration and flooding
Helminth				
Eccinococcus multiocularis	Northern Hemisphere	Foxes Rodents Small mammals	Direct	Deforestation Increase in rodent and fox hosts Pathogen spillover to dog Human expansion into forest, exposure of susceptible population

20

20: **"Forests and emerging infectious disease of humans"**
by: Bruce A. Wilcox and Brett Ellis

[19] The author states that, "in all about three fourths of recognized EID's either once were, or currently are, zoonotic, (i.e) transmitted between animals and humans (Taylor, Lantham and Woolhouse, 2001). Not surprisingly, the ancestry of pathogen causing the diseases can usually be traced to wildlife."

[20] The article inter alias provides a clear statement that the proximate cause of EID is deforestation.

> *"For those EIDs currently associated with forests, the proximate causal factors in their emergence include a combination of deforestation and other land use changes, increased human contact with forest pathogens among populations lacking previous exposure, and pathogen adaptation. Many may be transmitted among non-human primate hosts or insect vectors, and involve a variety of potential intermediate hosts including domestic animals. Of most concern, following initial local emergence a number of these diseases have demonstrated the potential to spread regionally or globally and become a significant threat to humans, domestic animals and wildlife populations.*[21]
>
> *Forests or deforestation per se are not the cause of either forest-associated infectious disease emergence or the globally increasing EID trend overall; EID causality is more complex than this. The main driver is the exponential growth in population, consumption and waste generation of the past several decades, which has driven the combination of urbanization, agricultural expansion and intensification, and forest habitat alteration that results in regional environmental change (see Box). The disease emergence process typically appears to be associated with a combination of these environmental factors. But the common factor is change – relatively abrupt or episodic social and ecological change. Most often this is reflected in changes in land cover and land use (unplanned urbanization and land use conversion), agricultural intensification (dams, irrigation projects, factory farms, etc.) and displacement and migration of people.* [22]
>
> *Like AIDS, most forest-originating EIDs are caused by viruses, although others are caused by bacteria, protozoans, helminths (worms) and fungi. These diseases are frequently not research priorities until they have become a threat to affluent populations, so knowledge about their distribution and biology is very limited in most*

21-22: **"Forests and emerging infectious disease of humans"**
by: Bruce A. Wilcox and Brett Ellis

cases. The historical orientation of tropical medicine towards understanding disease natural history and ecology was, unfortunately, abandoned with the advent of modern biomedicine and the mistaken belief that infectious diseases had been conquered by science (Gubler, 2001). Today's biggest research challenge is posed by the disciplinary gaps between infectious disease researchers, wildlife experts, ecologists and social scientists. The problems are of course compounded by the increasing numbers and densities of poor people living without potable water, sanitation and adequate public health infrastructure in developing countries." [23]

[**21**] A perfect example of Forest based Zoonotic and vector transmitted diseases has been explained as follows :-

"Yellow fever is the most well-studied disease from the standpoint of its association with forests (Monath, 1994). The virus that causes yellow fever is maintained in a transmission cycle of arboreal monkeys and sylvatic mosquitoes. Expansion into the forest by human settlements is a frequent cause of outbreaks. For example, the first outbreak of yellow fever in Kenya (1992 to 1993) involved a settlement where cases were limited to people collecting fuelwood and water, or possibly hunting in the forest. Much larger outbreaks occur when the transmission cycle leaves the forest canopy and extends to peri-urban and urban areas where the much higher density of humans and mosquitoes can fuel large epidemics (Sang and Dunster, 2001). This occurred in the Sudan in 2005, probably exacerbated by people fleeing areas of armed conflict and soldiers returning from forested areas. Environmental factors including abnormal rainfall may also have contributed to spreading the disease. The evolutionary capacity for rapid adaptation enables viruses to be transmitted efficiently in domestic or peri-domestic cycles. [24]

A number of other noteworthy forest-associated zoonotic EIDs do not appear to involve mosquitoes as vectors although their transmission cycles are not yet entirely certain. These include chikungunya, Oropouche virus, Ebola and simian immunodeficiency virus (SIV). The dramatic consequences of Ebola and SIV emergence have been evidenced over recent decades. HIV is a zoonotic SIV. SIVs have recently been found to be common in Old World monkeys (Galat and Galat-Luong, 1997). The hunting, butchering or illegal procurement of these animals not only is a major concern for conservation but also increases the risk of disease emergence (Wolfe et al., 2005). [25]

Many of the Ebola outbreaks have occurred in forest fringe areas, where expansion of human populations is bringing them into contact with pathogens that are foreign to them, particularly through more frequent contact with wildlife. This has led to a hypothesis that mechanisms associated with agricultural land use changes bordering forests and changes in the natural fauna may be involved in emergence (Morvan et al., 2000; Patz et al., 2004). Recently, it has

23-25: "Forests and emerging infectious disease of humans"
by: Bruce A. Wilcox and Brett Ellis

also been suggested that bats may serve as the reservoir for Ebola and that monkeys may contract the disease much as humans do (Leroy et al., 2005). Fruit bats are also important hosts of additional EIDs including Nipah and SARS viruses (Field et al., 2001; Lau et al., 2005)." [26]

[**22**] The authors explain the disease emergence pathway as follows :-

"The three categories of land use – urban, agricultural and natural habitat – represent an ecosystem continuum along a gradient from domestic to natural (left to right in the diagram). Three ecological trends are associated with these changes: vector and reservoir domestication (or peri-domestication); invasion of domestic habitat by opportunistic wildlife such as some rodents and blood-sucking arthropods (mosquitoes, ticks, midges and others); and invasion of the natural habitat by feral species such as domestic pigs, goats, rats, mice, dogs and cats. These species become pathogen reservoirs particularly in disturbed and fragmented forest adjacent to settlements. The convergence of human and animal hosts and reservoir and vector species within ecosystems, and the movement, shifting and mixing across the ecosystem continuum affects host–pathogen dynamics in a manner that facilitates disease emergence, as follows:

- *pathogens have increased opportunities for host switching (including adaptation to a new host);*
- *transmission is amplified and the opportunity for more rapid evolution is increased with multiple, interacting transmission cycles;*
- *pathogens' rate of infection exceeds the threshold required to produce an epidemic or an endemic disease owing to unprecedented population densities of the vector, the reservoir and susceptible human populations;*
- *pathogens evolve increased pathogenicity, infectivity and ability to avoid immune system detection, owing to increased opportunities for interaction of endemic infection cycles and pathogen strains, and greater density and genetic variability of pathogen populations."* [27]

[**23**] In conclusion, the author analyzes the impact of EID on the basis of change of forest environment and related activities.

"Emerging infectious diseases are considered to be among today's major challenges to science, global health and human development. Rapid changes associated with globalization, especially the rapidly increasing ease of transport, are mixing people, domestic animals,

26-27 : "Forests and emerging infectious disease of humans" by: Bruce A. Wilcox and Brett Ellis

wildlife and plants, along with their parasites and pathogens, at a frequency and in combinations that are unprecedented.

The role of and potential effects on forests and implications for forest resource management are significant. Forest land use changes and practices, particularly when unregulated and unplanned, frequently lead to increased prevalence of zoonotic and vector-borne diseases, and occasionally boost the prevalence of diseases capable of producing catastrophic pandemics. This should be a consideration in forest land use and forest resource planning and management*.*

In view of the enormous impact EIDs have on humans and economic development, including the economic impacts of diseases on agriculture and forestry, collaboration between the agricultural, forest and public health sectors is required to develop policies and practices for the prevention and control of EIDs. This will require substantial increases in the regulation, surveillance and screening of pathogens in transportation systems. ***Research on EIDs, particularly that involving the ecological epidemiology of zoonotic and vector-borne diseases associated with forests, needs to be integrated with forest resource management and planning. Greater emphasis is needed on integrating research and practice, for example through the development of forest management guidelines that can contribute to the control and prevention of EIDs. This will require increased interdisciplinary and collaborative research among foresters, forest ecologists, and wildlife and human infectious disease experts for better understanding of the role and impact of forests and forest land use and management on EIDs****."*[28]

(Emphasis supplied)

[**24**] In an another research article, **"Global shifts in mammalian population trends reveal key predictors of virus spillover risk"** published by the Royal Society on the Subject :- **Global Change and conservation,** Subject Area **:- ecology, health and disease and epidemiology**, the focus is on the impact of deforestation, the global shift in mammalian population and its effect on virus spillover risk: – In this well researched and documented article, they highlight the source of zoonotic diseases:

28: "Forests and emerging infectious disease of humans" by: Bruce A. Wilcox and Brett Ellis

"Emerging infectious diseases in humans are frequently caused by pathogens originating from animal hosts, and zoonotic disease outbreaks present a major challenge to global health. To investigate drivers of virus spillover, we evaluated the number of viruses mammalian species have shared with humans. We discovered that the number of zoonotic viruses detected in mammalian species scales positively with global species abundance, suggesting that virus transmission risk has been highest from animal species that have increased in abundance and even expanded their range by adapting to human-dominated landscapes. Domesticated species, primates and bats were identified as having more zoonotic viruses than other species. Among threatened wildlife species, those with population reductions owing to exploitation and loss of habitat shared more viruses with humans. Exploitation of wildlife through hunting and trade facilitates close contact between wildlife and humans, and our findings provide further evidence that exploitation, as well as anthropogenic activities that have caused losses in wildlife habitat quality, have increased opportunities for animal–human interactions and facilitated zoonotic disease transmission. Our study provides new evidence for assessing spillover risk from mammalian species and highlights convergent processes whereby the causes of wildlife population declines have facilitated the transmission of animal viruses to humans." [29]

[25] The impact of human population encroaching on wildlife and forests has been explained as under:

"Exploitation of wildlife through hunting and the wild animal trade have been hypothesized as increasing opportunities for pathogen spill over because of the close contact between wildlife and humans involved in these activities [4,12,24,25].
Human encroachment into biodiverse areas increases the risk of spillover of novel infectious diseases by enabling new contacts between humans and wildlife [28]. Slightly more than half of all threatened species (54.8%) were listed by IUCN because of the impacts of exploitation or habitat loss on species abundance indicating that this is a major impetus for species reductions. Our analysis incorporating data on species declines globally provides broad-scale support for convergent processes whereby exploitation of wildlife and habitat loss have caused wildlife population declines, as well as facilitated the transmission of animal viruses to humans that most likely occurred prior to and during large-scale losses in abundance." [30]

29-30: Global shifts in mammalian population trends reveal key predictors of virus spillover risk) by Christine K. Johnson, Peta L. Hitchens, Pranav S. Pandit, Julie Rushmore, Tierra Smiley Evans, Cristin C. W. Young and Megan M. Doyle)

[**26**] The article also provides details as to how domesticated species share the highest number of viruses with humans as also primates and bats. This becomes relevant in the present COVID-19 scenario.

> *"Domesticated species harboured an average of 19.3 zoonotic viruses (min 5, max 31) compared to wild species with a mean of 0.23 viruses (min 0, max 16). The top 10 mammalian species with the highest number of viruses shared with humans included eight domesticated species: pigs (n = 31 zoonotic viruses), cattle (n = 31 zoonotic viruses), horses (n = 31 zoonotic viruses), sheep (n = 30 zoonotic viruses), dogs (n = 27 zoonotic viruses), goats (n = 22 zoonotic viruses), cats (n = 16 zoonotic viruses) and camels (n = 15 zoonotic viruses). Aside from humans, accurate detection and reporting of zoonotic viruses would be most probable in domesticated species, given the economic and public health demand for these data. The only wild animals among the top 10 species with detected zoonotic viruses were the house mouse (Mus musculus) and the black rat (Rattus rattus), with 16 and 14 zoonotic viruses, respectively. Both of these species in the Rodentia order are considered invasive in most regions of the world, commonly inhabit domestic and peri-domestic structures, and have dubious non-domestication status given their use in laboratory studies and as pets worldwide. Sympatry, or spatial overlap of hosts, was highly correlated with cross-species transmission among rodents, and network analyses illustrate that the global distribution of the house mouse has facilitated the transmission of viruses to sympatric species around the world[29].*[31]
>
> *Primates and bats share more viruses with humans. We found that species in the primate and bat orders were significantly more likely to harbour zoonotic viruses compared to all other orders, after adjusting for domestication, trends in species abundance, criteria for listing and the number of PubMed publications at the species level (table 2). By contrast, Diprotodontia (marsupials) and Eulipotyphla (shrews, moles, hedgehogs) had fewer zoonotic viruses detected by the time of this study than species in other orders. A recent study evaluating the relationship between phylogeny and the proportion of viruses likely to be zoonotic for a given species also found that bats hosted significantly more zoonotic viruses than other orders and that primates drove the phylogenetic effect as a determinant of zoonotic spillover [5]. The close phylogenetic relationship of humans with non-human primates is recognized as a causal factor underlying spillover, reverse zoonoses and the coevolution of occasionally shared viruses [31]. Bats have also been repeatedly implicated as the source of recent emerging infectious disease events involving high consequence pathogens, including severe acute respiratory*

31: Global shifts in mammalian population trends reveal key predictors of virus spillover risk) by Christine K. Johnson, Peta L. Hitchens, Pranav S. Pandit, Julie Rushmore, Tierra Smiley Evans, Cristin C. W. Young and Megan M. Doyle)

syndrome (SARS) [32], Nipah virus encephalitis [33], and hemorrhagic fevers caused by filoviruses [34,35], and have been noted previously to host more zoonotic viruses per species than rodents [10]. Viral sharing has been shown to be more common among bat species than among rodent species and several bat traits have been associated with a higher propensity for cross-species transmission, including gregariousness (roosting in high densities) and migration [29]. With nearly a quarter of bat species lacking sufficient data for categorization of their IUCN Red List status, bats are probably still under-represented in field investigations and warrant future dedicated focus for emerging infectious disease research." [32]

[**27**] In fine, away forward has been suggested which we think may be of use to the authorities of Government who are in charge of protecting the environment and ecology and infectious disease control.

"Infectious diseases from wildlife have emerged at an increased pace within the last century [36] and are likely to continue to emerge, given expected increases in population growth and landscape change. Curbing disease emergence will prove challenging until we have a more thorough appreciation of the epidemiologic circumstances that facilitate pathogen spillover, particularly from wild animals, which are the source of the majority of recently emerging infectious diseases [2] and continue to constitute a substantial gap in disease detection efforts worldwide. Here, we find broad evidence supporting large-scale mechanisms underlying patterns of zoonotic virus richness across species, by which trends in mammalian abundance and drivers of declines among threatened species reflect animal–human interactions that facilitate virus transmission to people. By identifying a positive relationship between global trends in mammalian abundance and an increased number of mammalian viruses that have been shared with humans, our findings suggest that mammal species with larger global populations pose greater risk for virus spillover. Our data also provide new evidence that threatened wildlife species with limited extent of occurrence and small population sizes have shared relatively fewer viruses with humans, supporting the concept that virus spillover risk at this large scale is underpinned by the probability of animal–human interactions. Reservoir populations have a critical population or community size required for infectious disease transmission [37], and generally larger populations are more likely to propagate cycles of infection. Population range size similarly reflects opportunities for animal contact, and species with larger ranges should have increased potential to overlap in range, and possibly share habitat with other species, enabling cross-species transmission and increasing the risk of spillover to humans [29]. However,

32 : Global shifts in mammalian population trends reveal key predictors of virus spillover risk) by Christine K. Johnson, Peta L. Hitchens, Pranav S. Pandit, Julie Rushmore, Tierra Smiley Evans, Cristin C. W. Young and Megan M. Doyle)

determinants identified as predictors of zoonotic virus richness at this scale might not relate to zoonotic virus diversity in species at the local scale. Larger population size together with higher population density have been shown to positively correlate with higher viral richness among primate species [22], consistent with disease transmission mechanisms that are dependent on population densities and distributions.

Given we detected a significant increase in zoonotic virus richness among more globally abundant species, additional mechanisms underlying trends in wildlife populations warrant investigation. Species that have increased in abundance and even expanded their range despite large-scale anthropogenically driven landscape change and urbanization [38] are more likely to be generalist species that have adapted to human-dominated landscapes. Approximately one quarter of mammalian species had stable or increasing trends in abundance at the time of analysis, half of which were rodents [14]. While urbanization and landscape change towards crop production could decrease biodiversity overall, these activities can increase the abundance of select species [39]. Many species listed as least concern with increasing abundance by the IUCN Red List are adaptable wild mammalian species that have benefitted from a close relationship with humans. These species could have habitat and dietary niches that overlap with humans in dwellings or in agricultural practices, further enabling direct and indirect contact with similarly adapted sympatric species, domesticated species and humans. In particular, dwellings and agricultural settings are among the most high risk of interfaces for zoonotic viral transmission, particularly from rodents [4]. Pathogen transmission among animals thriving in human-dominated landscapes can also benefit from higher community size and density-dependent viral transmission, especially when resources that sustain mammal populations are aggregated [40], further increasing the probability of human contact with infectious reservoirs in these landscapes. With ongoing landscape transformation towards human-dominated landscapes and approximately half of the world's human population living in urbanized communities [41], species that are adaptable to human modified habitat are likely to continue to be an important source of zoonotic pathogen transmission" [33]

Surveillance activities that include animals and humans in close contact situations will advance outbreak preparedness in between outbreaks and assist in prioritizing in-depth, longitudinal field studies needed to understand epidemiological patterns in virus transmission and optimize disease prevention actions. Informed mitigation efforts aimed at ensuring biosafety in livestock production, minimizing interactions between wildlife and domesticated animals and limiting close contact with wildlife are especially needed given global trends in urbanization and food production. One Health surveillance approaches are needed that integrate animal and human health in monitoring for emerging infectious diseases and consider environmental change that is likely to intensify close proximity animal–human interactions in the near future. [34]

33-34 : Global shifts in mammalian population trends reveal key predictors of virus spillover risk) by Christine K. Johnson, Peta L. Hitchens, Pranav S. Pandit, Julie Rushmore, Tierra Smiley Evans, Cristin C. W. Young and Megan M. Doyle)

[**28**] These well researched articles clearly explain the need to keep the forest intact as much as possible and a Lakshman rekha needs to be drawn based on research and study of each forest. Effective collective study and monitoring is primary concern which needs to be addressed. The decapitation of forest has also caused very many ecological imbalance for long number of years.

[**29**] The Western Ghats of Indian Sub-Continent is a great repository of biodiversity. The "Shola forests" are one of the world's best preserved multi layered biodiversity. During the imperial governance millions of "Shola forests" trees were felled and as replacement exotic eucalyptus and wattle trees were planted on large mountain tracts in the Western Ghats. This resulted in severe environmental degradation and acute water scarcity in that region. Environmentalists were pursuing their pleas to restore the "Shola forests". The Madras High Court in Public Interest Litigation directed the Government to restore the "Shola forest" in a phased manner after obtaining orders of the Hon'ble Supreme Court in the case of**T.N. Godavarman Thirumulpad vs Union Of India &Ors: (2006) 10 SCC 486.**

[**30**] The issue is while on one side there is clarion call for halting the deforestation for the many reasons that we have highlighted earlier in this order, the need to restore lost forest has now become relevant due to the COVID-19 pandemic. The restoration of forest wherever destroyed will ensure that ecology is restored and bring back the fine balance that nature has envisioned for itself. In this regard, we would like to refer to the orders of

the Madras High Court to highlight the importance of preserving and restoring the forests all over India.

(i) Order dated 27.02.2014 passed in WP(MD) No.3633 of 2014;

> *This writ petition filed in public interest raises a very important issue with regard to the restoration of forests in the hill station of Kodaikanal, Nilgiris and other hill stations in Tamil Nadu including Western Ghats. The forests in these areas, more particularly, in Kodaikanal has dwindled due to various ecological imbalances. One important factor that has been pointed out in this writ petition is the impact of the commercial plantation of wattle and eucalyptus trees which have destroyed the Shola forests.*
>
> *2. Materials have been placed in support of the writ petition stating that the Shola forests were in existence in a wide area of Palani hills and Kodaikanal hills. This extent has been greatly reduced due to the destruction of Shola forests for commercial exploitation. Planting of wattle trees and eucalyptus trees has affected the eco-system in the Shola forest. The grass lands have also been affected. Consequently, the food chain right from the planktons to the panthers and tigers in the Shola forests, is affected. Various mammals and birds species in these areas, depend on the preservation and conservation of the Shola forest.*
>
> *3. The elevation of these hill areas has given a rise to tropical rain forests, more particularly, in Western Ghats. It is, these tropical rain forests, that provide best of ecology for all living creatures and sustain a good environment for the entire geographical location.*
>
> *4. In order to ensure that the valuable Shola forests and grass lands are maintained, effective steps have to be taken by the Department of Forests and Environments and the Principal Chief Conservator of Forests, Government of Tamil Nadu, Chennai, to ensure that Shola forests and tropical rain forests are restored to its original state. In this regard, the authority concerned has to take steps to annihilate wattle and eucalyptus trees in the forests of Kodaikanal hills, Palani hills and in the Western Ghats of Tamil Nadu region and save the forests.*
>
> *5. Taking serious note of the matter, the respondent authorities are directed to formulate a comprehensive scheme, if not already framed, for restoration of Shola forests and tropical rain forests in the Kodaikanal hills, Nilgiris, Palani hills and the Western Ghats. This should be done in a systematic and phased manner.*

(i) Order dated 10.08.2015 passed in WP(MD) No.3633 of 2014;

In general, forests stabilize the climate. The plants enrich the soil by recycling the nutrients through the shedding of leaves and seeds. They also regulate the water cycle by absorbing and redistributing rainwater quite equally to every species living within its range, which is known as the economy of water. Thus, forests provide perfect habitats for life to flourish on land. However, it is disheartening to note that the Tropical Montane Evergreen Forests, also known as "Shola Forests", are the most threatened ecosystems globally, because of the non-native invasive species. Shola Forests need to be protected. When it is the responsibility of every citizen to work for protection and promotion of forests and greenery by planting more and more trees as contemplated under Article 51-A(g) of the Constitution of India, which is extracted hereunder:

> *'It shall be duty of every citizen of India to protect and improve the natural environment including forests, lakes, rivers and wild life and to have compassion for living creatures.'*

the Courts would be equally zealous in protecting the Shola Forests from non-native invasive plant species. This system of thought led us to pass the order dated 27.2.2014.

2. In the said order dated 27.02.2014, it was very clearly stated that the nature of this writ petition is to restore the Shola forests and its natural habitat. This will help preserve the wild life sanctuaries at different locations in the State. This endeavour is to encourage the growth of indigenous species and remove exotic ones, which even as per the Department Study, are found to be detrimental to the indigenous trees and plants.

3. When the matter was taken up today, it is reported by the District Forest Officer, Madurai District, who is present in the Court, that the wattle and eucalyptus trees, which are exotic species, have the tendency to draw more water for their growth, resulting in reducing the water table. The exotic species does not permit the indigenous species of the Shola forests to survive.

4. Wattle and eucalyptus are commercially exploited for State revenue. The dichotomy between the State revenue and preservation of ecology is, therefore, the ground reality that has to be addressed. Looking at the larger perspective of preservation of forests, more particularly, wild life sanctuaries, the need to preserve and restore Shola forests, other forests and grass lands, etc., which is comprised of indigenous species, will be appropriate for ensuring ecological balance of our biodiversity.

5. This suggestion of the District Forest Officer is the subject matter of a detailed analysis by an Expert Committee which has been formed on the basis of the order passed by this Court on 27.02.2014. Series of meetings have been convened and we have *noted it. A resolution for conducting the meeting was taken by the Additional Chief Secretary, Environment and Forests Department, Secretariat, Chennai, on 12.03.2014. In the meeting, the scope of analysis has been segregated as follows:*

(a) Working Plan;
(b) Government Orders;
(c) Long Term Strategy;
(d) Supreme Court of India Orders; and
(e) Management Plan in Kodaikanal Division.

Based on that, on 26.03.2014, the following persons were nominated as Members of the said Committee:

Sl.No.	*Name and Designation*	*Position in Committee*
1.	*Thiru.Basavaraju, I.F.S. Chief Conservator of Forests, (Research)*	*Chairman*
2.	*Conservator of Forests, Coimbatore*	*Member and Co-ordinator in respect of Nilgiris Hills.*
3.	*Conservator of Forests, Dindigul.*	*Member and Co-ordinator in respect of Kodaikanal Hills*
4.	*District Forest Officer, Nilgiris North Division.*	*Member.*
5.	*District Forest Officer, Nilgiris South Division.*	*Member.*
6.	*District Forest Officer, Kodaikanal Division.*	*Member.*

The terms of references of the Expert Committee, are as follows:

"(i) To study the wattle and Eucalyptus menace in the Shola and other forests of Tamil Nadu.

(ii) Suggest possible methods to eliminate the wattle and eucalyptus trees from the forests of Tamil Nadu.

(iii) Post for the conservation, protection and rejuvenation of the forests in Western Ghats Region within the State of Tamil Nadu.

(iv) The Chairman of the Expert Committee may pursue necessary action and issue direction to the Committee members as deemed fit and proper from time to time and sent action taken report to the Principal Chief Conservator of Forests at least on bimonthly basis.

(v) A separate comprehensive study report comprising all the above aspects for restoration Shola and rain forest separately in respect of Kodaikanal and Nilgiris District may be submitted in 10 copies.

(vi) The study report shall consists the entire area of region shola area of the earlier period / shola area in the present / area planted invaded by wattle / eucalyptus and pine.

(vii) Period of operation to replant the area to restore the shola forest and rain forest with indigenous species.

(viii) The study report shall also contains the present methodology and project being implemented and its impact and results.

(ix) The financial implication which includes revenue by the sale of wattle / eucalyptus / pines and also the expenditure for replanting / maintenance with replacement of causality conservation / protection for 2/3 plan period (Working Plan/Management Plan period).

(x) The committee may co-opt any person based on the need for formulation of strategy for eradication of Wattle/removal of Eucalyptus.

(xi) The Committee may also examine the various methodology (removing the seeds at present in the field, clear felling wattle plantations, felling the wattle and eucalyptus plantations and replanting with indigenous species, after removal exotic species, the area may be conserved by fencing to facilitate the natural generalists regrowth of indigenous species and other methods). The plan for removal of wattle/Eucalyptus may be worked out for 2/3 Working Plan/Management Plan Period. Committee may suggest strategy under (a) short strategy (b) Long strategy on scientific ecological principle.

(xii) Any other related issue for removing the exotic species and restoring shola and rain forests."

(extracted as such)

This agenda, by and large, addresses the issue raised in the writ petition for restoring the native Shola forests, forests and grass lands, etc. The Expert Committee met on 11.04.2014 at Coimbatore.

6. It is reported that thereafter another National Workshop was conducted on 13.02.2015 and the issue is under serious *consideration by the Committee concerned as well as the Government.*

7. The District Forest Officer states that this is the first time such a measure is taken to look at the problem in a different perspective and bring about the restoration of Shola forests, forests, grass lands, etc. by removing the exotic species which even according to the Department, are detrimental to the forests and sanctuaries in many respects. Besides they draw more ground water and deplete the water table. This is causing serious environmental degradation.

8. We also note that there is no reference to alien species or exotic species in anyone of the statutory Acts, namely, the Tamil Nadu Forests Act, 1882, or the Wild Life (Protection) Act, 1972. This is significantly important as the authorities have to assess and formulate schemes for removal of exotic species and to manage and restore the native Shola forests, forests and grass lands, etc.

9. At this juncture, it was brought to the notice of this Court that referring to the order of this Court dated 27.2.2014 and the consequential meetings of the Expert Committee, the First Bench of the Madras High Court, by order dated 17.12.2014 passed in W.P.No.16857 of 1991 (K.Ussainar v. The State of Tamil Nadu, MANU/TN/3156/2014) held as under:

> *"12. The aforesaid thus shows that the Expert Committee is looking into the matter, whose report is stated to be expected soon. The Government Order in G.O.Ms.No. 289, Environment and Forests Department, dated 09.10.2014 has also been issued, allotting 42,594 tonnes of eucalyptus blue gum trees and 27567 tonnes of wattle trees to TNPL from the Nilgiris North Division, to be removed within a period of one year. The area will be restored with indigenous species to its originality and these two trees are stated to be in the process of removal in a systematic manner.*
>
> *13. Despite the aforesaid, it has been pleaded that permit in Form-I from private area and permit in Form-II under Timber Rules would be required for transportation of wattle trees and bark from the forest area, as the act of peeling off bark is stated to be an act amounting to cutting or causing to cut a tree and the act of peeling off bark is stated to be the death of the wattle trees and such trees may die without corresponding activities for re-plantation of the trees. A comprehensive plan under the forest department is stated to be under consideration and even the removal of wattle trees from the private areas is required to be coded to maintain the eco sensitivity of the area, otherwise the tree cover*

would be completely wiped out. The problem has been sketched out in paragraph 16 as under:

> *'16. It is respectfully submitted that the predominant idea is to remove the exotic species and restore of the grassland. In order to accomplish this goal is rather simple cut the invasive trees and the grasslands will return. In this case, the private land owner is not going to allow grass lands or sholas to come in their own land by removing the exotic species. Any management interventions should be implemented with caution, patience, and initially on a small scale. The landscape is variable, which means different sections on the landscape should get different levels of priority and interventions. Thus, the existing law may be enforced in the private lands and the management of private lands in to its originality with biodiversity is to be planned after the restoration plan in forest areas for a considerable period mixing up will definitely bring malpractices and illegal activities which is injurious to the fragile ecosystem of the Nilgiris.'*

1. *In the aforesaid conclusion of the factual matrix, it is suggested that since an Expert Committee has already been constituted, the question as to whether wattle bark should be permitted to be removed without the requirement of any regulation may be examined by that Expert Committee itself. Such a course of action is acceptable to both the parties. We are, thus, of the view that this issue, keeping in mind the conspectus of the stand of the two parties, as recorded aforesaid, be referred to the Expert Committee, which would take a considered decision within a maximum period of three months from the date of receipt of the order. In that process, all interested parties, including the petitioner, may be heard and a reasoned decision be taken."*

10. In our endeavour to find a solution to this pivotal issue, we leafed through large volumes of materials, and would like to reproduce some of the suggestions given by one Dr.FarshidS.Ahrestani, who is Postdoctoral Scholar, Department of Biology, Eberly College of Science, The Pennsylvania State University, which in turn are based on our order dated 27.2.2014. An excerpt from the article titled "To chop, or not to chop? The issue of exotic invasive trees in the Western Ghats" is as under:

> ***"Is there a solution?***
>
> *The petition filed in the courts asks that the Forest Department get rid of the exotic invasive trees to restore the*

grasslands. The predominant idea to accomplish this goal is rather simple – cut the invasive trees and the grasslands will return. Although there is a poor understanding of the exact mechanism that was responsible for establishing the shola-grassland ecosystem, there is little debate that the process took hundreds, if not thousands of years. Intensive plantation activity for over 40 years, followed by wide-spread invasion by non-native trees for 20 years have surely modified the soils and water tables in the region significantly. Therefore, is it reasonable to expect a system that took thousands of years to evolve, but has been extensively modified for over 60 years, to easily restore itself to a former state? The short answer to this question is "Probably not", which is why we need to acknowledge that we are dealing with a complex issue that probably requires more than the simple solution of chopping down the invasive trees.

What do we do?

There are no clear answers to the restoration process. Any management interventions should be implemented with caution, patience, and initially on a small scale. The landscape is variable, which means different sections on the landscape should get different levels of priority and interventions. The long term needs to be kept in mind – modifications to the landscape lasted 60 years and we have waited twenty years since the end of plantation activity to intervene. We, therefore, need to be patient with the restoration process and not expect large-scale changes in the short-term. Any removal of trees has to be done keeping in mind the needs of the local people for firewood, both for cooking and heating. Unless some effort is made to reduce the dependency that the local people have had on firewood for hundreds of years in the region, we cannot expect this dependency to disappear any time soon. Fortunately the Mukurthi Wildlife Sanctuary in the Niligiri Hills and the Kodaikanal Wildlife Sanctuary in the Palni Hills provide the department with ample opportunity to experiment with management interventions while provisioning for the needs of local people using buffer regions for firewood. For the grasslands to make a comeback they will require assistance and a strong long-term commitment from us. The following suggestions could help address the court order in the short-term and the restoration process in the long-term (the suggestions are targeted at the Palni Hills, but are applicable to the Nilgiris too):

- *Prioritize the remaining grassland patches: There are a few remaining grassland patches. These, however, are not completely free of invading non-native trees. Many of these patches are found at the western region of the newly declared Kodaikanal sanctuary, and are far away from human habitation. However, by the same token they are generally difficult to access, often only by foot. Maintaining these remote grasslands patches free of invasive trees and shrubs might turn out to be an expensive endeavour, which requires a strong commitment from the Government to bear these costs.*
- *Thinning of plantations: Shola trees are regenerating within many plantation patches — an invasion of native trees into patches of non-native trees. Ideally we would prefer grasslands to make a comeback, but grasses cannot compete as well as native shola trees can with the invasive trees for sunlight. It makes little sense to kill colonizing shola trees especially since there is no guarantee that grasslands will return to their entire former range. To help shola trees succeed in their colonization, we could help by thinning, i.e., cutting select invasive trees around them. This management intervention is relatively inexpensive and we could experiment with different strategies, i.e., cutting select trees with no additional intervention in some areas, and in others areas cutting select trees, but following up with removal of saplings. Trying different methods will allow the Department to compare the effectiveness and cost to benefit ratios of different intervention strategies.*
- *Begin mass tree removal with a pilot phase :*
- *Chopping down all the invasive trees would be a staggering endeavour and could lead to further ecological issues. It is common knowledge that large-scale tree removal always affects the soil layer for the worse, either by modifying soil composition or by soil loss. The shola-plantation/grassland landscape plays an important role as a watershed that supplies water to millions of people. It is likely that the plantations have altered the water table for the worse, but it is unlikely that large-scale cutting of plantations would improve the situation. Therefore, it would be best to begin mass tree removal with a pilot phase.*
- *It would be a good idea to remove trees en masse in 1-2 sizeable (~10 hectares) experimental plots deep inside the Kodaikanal Sanctuary that preferably do not have invading shola tree species (in general, further the distance from a shola patch, less the chance of finding*

colonizing shola trees). Keeping in mind that this restoration process is meant to benefit wildlife, and that we need buffers of wattle to satisfy the prevailing high demand of firewood, it is important that these plots are not within easy reach of people. It would be best to choose plots that are easily accessible, for example besides a road (an ideal location for both plots would be around Berijam lake). These plots will require constant support to provide the best conditions for grasses to make a comeback, mainly the regular (every 3-4 weeks) removal of seedlings of non-native trees and native woody shrubs. It is highly likely that Based on the supplementary planting of native grasses will be required.

- *Based on the lessons we learn from restoring grasses in these initial experimental plots for a period of 2-3 years, we can then expand the scope of removal to other adjacent non-native tree plantations. There are also lessons waiting to be learnt from a few mass tree cuttings that the Forest Department has conducted over the last decade."*

This is one suggestion that emanates from a scholar. The restoration of Shola forests, forests and grasslands, etc., has to be considered on the basis of expert opinion, data on impact of exotic species, environmental damage already caused and possible pitfalls in taking up such a project.

11. In the book titled "RAINFOREST RESTORATION - A GUIDE TO PRINCIPLES AND PRACTICE", some of the points which we found of great significance are as under:

"How do we prioritize areas in the landscape for restoration?

Sites need to be prioritized for restoration in forest landscapes using specific criteria based on ecological and conservation needs. This could include, for instance:

• sites that are habitats of particular threatened or endemic species,

• stream sides and river courses,

• degraded areas within or along the edges of existing wildlife sanctuaries and reserved forests,

• edges of forest fragments, adjoining plantations or other habitats

• corridors linking forest fragments,

• along linear intrusions such as roads, power-line clearings, and fie-lines, and

• the land matrix (plantations, filds, streams etc.) surrounding fragments or reserves

...

Why should we deal with alien species?

Many alien species (e.g., Eucalyptus spp., Acacia auriculiformis, Acacia mearnsii, pines, Casuarina equisetifolia) have been planted widely, even inside wildlife sanctuaries and national parks. In addition, many herbaceous weeds have been introduced and spread due to various human activities and regular small-scale disturbances. Sometimes alien species have been planted as they are considered to provide food for wildlife (e.g., Maesopsis eminii). These alien species have various detrimental effects on natural ecological processes, native vegetation, and many wildlife populations through:

• Reduction in ground water table (e. g., Eucalyptus spp.)

• Alteration of soil characteristics and microclimate

• Suppression or alteration of native plant communities (e.g., Maesopsis eminii)

• Proliferation of other weeds (e.g., Lantana camara often grows in the understorey of Eucalyptus plantations)

• Change in forest structure and function (many alien species)

• Invasion into surrounding landscape (many alien species, Maesopsis eminii, Acacia mearnsii, Spathodea campanulata)

• Reduction in native biological diversity, particularly affecting specialized mature forest animal species

How do we deal with alien species?

A basic principle is that one should strictly avoid planting alien species close to or within wildlife conservation areas. Alien species need to be dealt with care. Most restoration programmes employ means of targeted removal or suppression of invasive alien species. These may include cutting and uprooting of rootstock as in the case of Lantana camara, hand-weeding, pressing down of grasses with boards, or even herbicide application on specifi weeds. Care should be taken in such weeding operations not to disturb soil or native vegetation as disturbances can lead to further proliferation of weeds. Occasionally some alien species may prove useful in restoration, if they are non invasive, by providing partial shade or leaf litter that may act as mulch.”

These are questions that have been posed by scholars and nature activists. There is a need to prepare a comprehensive scheme for restoration of native forests and grasslands, etc. Individual countries would have to develop their own model. The trial and error method adopted by different countries can be a pointer for our experts to tread this issue in a meaningful and comprehensive manner.

12. We hope that the officials of the Department will consider the above said materials also and provide answers to these issues and give suggestions for amendment of the relevant provisions of the Act to address the above issues. The effect of damage that is caused by the exotic species to the indigenous trees and plants, should be assessed, controlled or managed or eradicated with an object to restore the indigenous forests and plants for the development of the Shola forests, forests, grass lands, etc. This will restore the wildlife habitat besides helping the climactic cycle and enhance the depleted water resource. ***"Save the Shola and Safeguard the Environment"*** *- is the mantra appropriate for the present climatic calamities. There are many Districts in this State that have been declared drought-stricken. There is hardly any vegetation or agriculture operations. In fact, agrarian economy of India is fast changing. Urban development is the new wave that is changing the social milieu. The forest alone is the buffer to the fast changing rural transformation. These are some of the vital issues to be seriously considered during the course of the Special Committee deliberation for formulating a long term strategy.*

13. ***We make it clear that in our order dated 27.02.2014, there is no direction as such to cut or remove the exotic species, viz., wattle, eucalyptus trees, etc. All that we said is that a comprehensive scheme has to be prepared in consonance with Section 33 of the Wild Life (Protection) Act, 1972.***

(emphasis supplied.)

14. It is also stated by the District Forest Officer that the restoration of Shola forests, forests and grass lands, etc., has been the subject matter of much debate on various levels throughout the country and the Government has to take a decision in the matter taking into consideration the ecological impact, revenue implication, impact on forest dwellers and forest produce, etc.

15. We agree to the view that it is for the Government to formulate a policy and implement the scheme to protect the indigenous trees and plants and to take steps to prevent the Shola forests, forests and grass lands, etc., from the onslaught of exotic *and invasive plant species. The policy should also include restoring the Shola forests, forests and grasslands, etc. This principle may also apply to other exotic plants, shrubs, wild animals, birds and fish, etc. The impact of exotic and invasive species, we find, is very extreme and very costly to reverse. To cite a few examples, Seemai Karuvela trees (Prosopis juliflora), rampant in Tamil Nadu and Lantana (Lantana camara) (small perennial shrub) in Western Ghat hills - Ottacamand and Kodaikanal. These invasive species out-compete other more desirable species, leading to destruction in biodiversity. It can also cause problems if it invades agricultural land. As a result of its toxicity, it may affect livestock. It has the ability to form dense thickets if left unchecked can greatly reduce the agricultural productivity and destroy farm land, besides affecting very biodiversity and dynamics of that area.*

16. Article 48-A of the Constitution of India mandates that 'the State shall endeavour to protect and improve the environment and to safeguard the forests and wild life of the country.'

17. Further, Article 51-A(g) of the Constitution of India speaks about the fundamental duties of citizen in this regard. - 'It shall be duty of every citizen of India to protect and improve the natural environment including forests, lakes, rivers and wild life and to have compassion for living creatures.'

18. We cannot but lay emphasis on this issue any better than the intent stated in the Indian Constitution.

19. Over the last many decades, a number of Forest Invasive Species, without realizing the consequences, have been introduced in India knowingly or unknowingly. The invasive species are further categorized as floral (weeds and plants having national and regional distribution), entomological (insects) and pathogenic (fungi). Approximately, 111 of such species have been identified across the country under the above mentioned categories. No systematic studies have been carried out so far to inventorize the Invasive Species. However, it would be useful to have a detailed inventory of such invasive species in different ecosystems of Tamil Nadu and in the entire country. Appropriate strategies will have to be devised for their control, eradication and management in connection with various stakeholders and for restoration of endemic native species in a phased manner.

20. The primary concern for the Government is to ensure that any form of exotic varieties of trees, plants, shrubs, wild animals, birds or fish, etc. are systematically removed, so that, it does not endanger the indigenous ones. This aspect of the matter has to be considered by the Government with all earnestness. No *doubt, the Department concerned has to make a proposal to the Union Environment Ministry for removal of these exotic species and on such approval of the said proposal, it needs to be placed before the Honourable Supreme Court for final clearance in view of various orders that have been passed in **T.N. Godavarman Thirumalpad (89) v. Union of India** reported in **(2006) 10 Supreme Court Cases 486.***

*21. The Honourable Supreme Court in **T.N. Godavarman Thirumalpad (89) v. Union of India** reported in **(2006) 10 Supreme Court Cases 486**, in paragraph 10, held as under:*

> *"10. None of the States has filed any objection to the recommendations of CEC made in paras 14 and 15 in relation to clarification about allowing conservation and protection related activities for better management of the protected areas. The recommendations contained therein are, accordingly, accepted and the order dated 14-2-2000 [T.N. Godavarman Thirumalpad (27) v. Union of India, (2002) 10 SCC 634] is clarified accordingly. Accepting the said recommendations, we direct as under:*
>
> *(A) Various activities such as removal of weeds, clearing and burning of vegetation for fire lines, maintenance of fair weather roads, habitat improvement, digging temporary waterholes, construction of anti-poaching camps, chowkies, checkposts, entry barriers, water towers, small civil works, research and monitoring activities, etc. are undertaken for protection and conservation of the protected areas and therefore permissible under the provisions of Section 29 of the Wild Life (Protection) Act, 1972. These activities are necessary for day to day management of the protected areas besides they do not involve any type of commercial exploitation.*
>
> *The activities abovementioned are permissible under the various provisions of other environmental laws as well.*
>
> *(B) The order dated 14-2-2000 [T.N. Godavarman Thirumalpad (27) v. Union of India, (2002) 10 SCC 634] will not be applicable to the following activities provided that they (i) are undertaken as per the management plan approved by the competent authority; (ii) are consistent with the provisions of the Wildlife (Protection) Act, 1972; (iii) are undertaken consistent with the National Wildlife Action Plan; (iv) are in conformity with the guidelines issued for the management of the protected areas from time to time; and (v) the construction and related activities are designed to merge with the natural*

surroundings and as far as possible use forest friendly material.

(a) Habitat improvement activities

Weed eradication, maintenance and development of meadows/grassland required for wild herbivores which are prey base for the carnivores, digging and maintenance of small waterholes and small anicuts, earthen tanks, impoundment of rainwater, relocation of villages outside the protected areas and habitat improvement of areas so vacated.

(b) Fire protection measures

Clearance and maintenance of fire lines as prescribed in the management plan by undertaking controlled cool or early burning and construction of watch towers.

(c) Management of wet grassland habitats

Early or cool controlled winter burning of grassland habitats such as in Kaziranga and Manas National Parks in Assam, to facilitate growth of fresh grass.

(d) Communication and protection measures

Construction of wireless towers, improvement and maintenance of fair weather non-tarred forest roads not exceeding three metres in width, small bridges, culverts, fences, etc.

(e) Anti-poaching initiatives

Construction, maintenance and improvement of small anti-poaching camps/chowkies, patrolling camps, checkposts, barriers, boundary walls, construction of small staff quarters for the front line staff, etc."

and such other order or orders that may be passed from time to time.

22. Recording the above, we adjourn the matter to ***12.10.2015****, so as to enable the respondent Department to give us a Status Report on the suggestions that they are coming up with the Management Plan for the Sanctuaries and Working Plan for the Reserved Forests.*

23. At this juncture, this Court is only facilitating the concept of Restoration of Shola forests, forests, grass lands, etc., and helping for the indigenous species.

(iii) Order dated 26.10.2015 passed in WP(MD) No.3633 of 2014;

In our order dated 27.02.2014, we directed the Principal Chief Conservator of Forests, Government of Tamil Nadu, Chennai, to formulate a comprehensive scheme for restoration of Shola Forest, on a systematic removal of wattle and eucalyptus trees. Thereafter, another order was passed on 10.08.2015, based on the in-puts given by the District Forest Officer, Kodaikanal.

2. At this juncture, the District Forest Officer, Kodaikanal, produced a Report of Expert Committee on Comprehensive Study for the removal of alien and invasive species and restoration of sholas and regeneration of grasslands in Nilgiris District in Tamil Nadu, which is submitted by Dr. H. Basavaraju, I.F.S., Chairman of Expert Committee and Additional Principal Chief Conservator of Forests (Wildlife). In this Expert Committee, there is a Sub-Committee for which Mr. D. Venkatesh, District Forest Officer, Kodaikanal Division, is the Chairman. The Detailed Report provides, various technical as well as financial aspects of the project for restoration of shola forest, grasslands, etc. This, according to the District Forest Officer, Kodaikanal Division, has been placed before the Department of Environment and Forest, Government of Tamil Nadu, who have given their approval and then it has been placed before the Finance Department, Government of Tamil Nadu and the Finance Department has also approved it. We record the same.

3. Mr. D. Venkatesh, District Forest Officer, Kodaikanal Division, states that the matter has been forwarded to the Government for its consideration. Taking note of the technical as well as financial aspect of the matter on which the file is resting with the Government for the present, we request the Principal Secretary to Government, Environment and Forest Department, Government of Tamilnadu, the 1st respondent herein and the Principal Secretary, Department of Revenue, Government of Tamil Nadu, to pursue the matter with the Government and ensure that approval is granted, subject to the evaluation of the report by all concerned. We expect the Government to finalize the report of the Expert Committee, at the earliest. Thereafter, the Government will have to move the Hon'ble Supreme Court, in terms of paragraphs 20 and 21 of our order dated 10.08.2015.

4. The District Forest Officer, Kodaikanal, has also taken pains to address the Court, with photographs, showing restoration of shola forest in certain pockets of Kodaikanal Hills, i.e. Mathikettan Solai, etc., based on the Government's approved scheme, by removing invasive plants. This shows that the Department is aware of the urgent need to restore shola forest and grasslands and to remove invasive and exotic species. Consequent to the shola forest restoration measures taken, wild animals like Nilgiri pipet, porcupine, barking deer, tiger, leopard cat, gaur, etc. are sighted. It *shows that there is scope for improving and enhancing shola forest and grassland. We record with appreciation the work already done so far. To enable the respondents to file a comprehensive report on the further action taken, list the matter on 14.12.2015.*

5. With the above direction, we adjourn the matter for enabling the Government to file a status report and a comprehensive report on the further action taken. Presence of the District Forest Officer, Kodaikanal, is recorded. His valuable assistance is also recorded and appreciated."

[**31**] The above issue also addresses the impact of deforestation and its ill effect on climate change, environment and decline in forest dwelling plants and animal species. We only hope that the Government of India, Ministry of Environment, forest ecology and climate change have taken serious note of the effect of deforestation and invasion of exotic species.

[32] The Forest (Conservation) Act, 1980 (Act 69 of 1980) was enacted for the reasons that deforestation causes ecological imbalance and leads to environmental deterioration. Deforestation has taken place on a large scale in the country which is of great concern and with a view to check further deforestation, the Forest (Conservation) Act, 1980 has been enacted by the Parliament in the year 1980. Section 2 of the Forest (Conservation) Act, 1980 reads as follows:-

"2. Restriction on the de-reservation of forests or use of forest land for nonforest purpose: Notwithstanding anything contained in any other law for the time being in force in a State, no State Government or other authority shall make, except with the prior approval of the Central Government, any order directing-

(i) that any reserved forest (within the meaning of the expression reserved forest" in any law for the time being in force in that State) or any portion thereof, shall cease to be reserved;

(ii) that any forest land or any portion thereof may be used for any non-forest purposes;

[(iii) that any forest land or any portion thereof may be assigned by way of lease of otherwise to any private person or to any authority, corporation, agency or any other Organisation not owned, managed or controlled by Government.

(iv) that any forest land or any portion thereof may be cleared of trees which have grown naturally in that land or portion, for the purpose of using it for afforestation.

2 [Explanation:- For the purpose of this section "non-forest purpose" means the breaking or clearing of any forest land or portion thereof for-

(a) the cultivation of tea, coffee, species, rubber, palms, oil-bearing plants, horticultural crops of medicinal plants;
(b) any purpose other than reafforestation, but does not include any work relating or ancillary to conservation, Development and management of forests and wildlife, namely, the establishment of check-posts, fire lines, wireless communications and Construction of fencing, bridges and culverts, dams, waterholes, trench marks, boundary marks, pipelines or other like purposes.]

[**33**] Similarly, to protect wild animals, birds and plants, so as to ensure ecological and environmental security of the country, Wild Life (Protection) Act, 1972 (Act 53 of 1972) was enacted. The prohibition on hunting of wild animals under this Act is covered under Chapter III Section 9.

"**9. Prohibition of hunting** :- No person shall hunt any wild animals specified in Schedules I, II, III and IV except as provided under section 11 and section12."

[**34**] Chapter IIIA deals with Protection of Specified Plants.

"CHAPTER-IIIA

PROTECTION OF SPECIFIED PLANTS

17A. Prohibition of picking, uprooting, etc., of specified plants. – Save, as otherwise provided in this Chapter, no person shall –

(a) willfully pick, uproot, damage destroy, acquire or collect any specified plant from any forest land and area specified, by notification, by the Central Government,

> (b) possess, sell, other for sale, or transfer by way of gift or otherwise, or transport any specified plant, whether alive or dead, or part or derivative thereof :
>
> Provided that nothing in this section shall prevent a member of a scheduled tribe, subject to the provisions of Chapter IV, from picking, collecting or possessing in the district he resides any specified plant or part or derivative thereof for his bonafide personal use."

[35] In the backdrop of the above laws, the illegal encroachment of forests and intentional clearing of the forests for human settlement should be closely monitored under the provisions of the Forest (Conservation) Act and also on the basis of the directions issued by the Hon'ble Supreme Court in the case of **T.N. Godavarman Thirumulpad vs Union Of India & Ors : (2006) 10 SCC 486.** The same applies to illegal hunting of wild animals, birds, picking and uprooting specified plants which are the bio-diversity of the forests. Any form of illegal encroachments into the forests and the illegal activities like burning down the forest, illegal hunting of wild animals should be strictly forbidden. Instances of fire being caused in the reserved and protected forests are cited by the learned Addl. Advocate General, Shri Lenin Hijam. It was stated that there were 11340 forest related wild fires in the State of Manipur between January, 2020 and June, 2020. This data, as stated, is a very serious issue which the State Government has to tackle on a war footing. The allegations made by the petitioner's Association in the Public Interest Litigation stands justified in the light of the above statement. In fact, the petitioner's Association have referred to a paper report dated 13.4.2020, stating that a portion of Cheiraoching under the Langol Reserved Forest Area was set on fire. Similarly, some portion of the Nongmaiching Hill under the Nongmaiching Reserved Forest area was also set on fire on the same day. On 15.4.2020, a portion of the forest under the Gwarok Reserved

Forest under Thoubal District was also set on fire. This was reported on 16.4.2020. It is, however, heartening to note that the Forest Department has initiated and ensured the removal of unauthorised houses constructed in the Langol Reserved Forest area on 25.04.2020. While it is commendable that steps have been taken as above, it is necessary to note that the protection of forests from such illegal acts coupled with restoration of forests which are already denuded for various reasons should be taken up as a priority. Respondents No.1 to 5 are directed to strictly implement the provisions of the Forest (Conservation) Act and Rules and Wild Life (Protection) Act, 1972 and Rules.

[**36**] A cumulative and scientific approach as indicated above will ensure that the existing forest cover is protected. Similarly, conservation and restoration of forests are also necessary for maintaining and restoring the environment and ecology. The need to protect the forest, its diverse species and the wild life, to avoid pandemic like the present one COVID-19 has been highlighted by many professors in the field of Science.

[**37**] Professor Carl Bergstrom of University of Washington an authority on pandemic and infectious disease has this word of caution in the midst of COVID-19 pandemic.

> *"There are ever so many animals viruses that are yet to come and cause global pandemics which make it imperative that we protect forests, reforest empty lands and provide buffer zones separating humans and wildlife to prevent such extinction events from occurring again and again. From Financial Times April 9, 2020, 10:45 am by Johanes Vogel. The writer is director-general of the Museum of Natural History, Berlin, the Leibniz Institute for Evolution and Biodiversity Research and a professor at the Humboldt University."*

[**38**] In a related but more emphatic article published in the Financial Times April 9, 2020 by Johannes Vogel, Director General of the Museum of Natural History, Berlin, Laibniz Institute for Evolution and Biodiversity Research and a professor at the Humboldt University markedly places the present COVID-19 pandemic on indiscriminate arrogant human interrelation with nature as a primary cause. The human involvement and its impact on nature is a fundamental cause for the series of infectious diseases and the zoonotic virus transmission. He explains the role of human beings as the cause of the pandemics as follows:-

> *"As the Covid-19 pandemic spreads around the planet, we have become part of a natural experiment. A virus has crossed the species line and is now travelling like wildfire through its new host. Normally, natural landforms such as mountains, oceans or canyons slow the spread of such outbreaks. But this virus has taken hold of a cosmopolitan species – a highly mobile, super-numerous and super-networked one humans. We pay too little attention to the fact that our arrogant relationship with nature fuels, and even causes many of humanity's greatest challenges. The threats we face are interrelated: climate change, the loss of biodiversity and the emergence of entirely new pathogens that threaten us time and again. Countries are flooded, forests burn, glaciers melt, oceans warm and insects die, all through our actions. Pathogens break, through species boundaries because we are exploiting natural resources without respect. For example, overfishing in the coastal waters of many African countries by foreign fleets leads local populations increasingly to turn to bushmeat for sustenance, increasing the likelihood (as with Ebola) that pathogens will be transmitted to humans. Markets that trade wild animals as well as pets and farm animals are ideal locations for pathogens to cross boundaries.*
>
> *This was demonstrated in the Sars outbreak of 2002/2003, which some virologists attribute to contact with the civet cat that is eaten as a delicacy in parts of China. There are indications that the current coronavirus outbreak also spread to humans at a wildlife market in the Chinese city of Wuhan. Our health and wellbeing as a species are linked to how we define our place in nature. Seeing ourselves as masters of our universe, we kill and sell whatever we want – even if that is bats or pangolins. Billions of dollars' worth of wild animals and*

plants are traded globally. Not every trade contributes to the destruction of biodiversity, but unsustainable and ruthless trade in wildlife destroys the diversity of nature.

Animal (zoonotic) virus transmission risk has been highest from animal species that have increased in abundance and even expanded their range by adapting to human-dominated landscapes. Domesticated species, primates and bats were identified as having more zoonotic viruses than other species. Among threatened wildlife species, those with population reductions owing to exploitation and loss of habitat shared more viruses with humans. Exploitation of wildlife through hunting and trade facilitates close contact between wildlife and humans, and our findings provide further evidence that exploitation, as well as anthropogenic activities that have caused losses in wildlife habitat quality, have increased opportunities for animal-human interactions and facilitated zoonotic disease transmission."

[**39**] It is, therefore, clear that destruction of forests and invasion/intrusion of human beings in the forest domain displacing forest species appears to be a major factor for the series of diseases like the present COVID-19 ("**For Experts Who Study Coronoviruses, a Grim Vindication**," by Charles Schmidt).

[**40**] What is the way forward is a question looming on humanity. In the midst of COVID-19, many countries are testing different methods to tide over the pandemic. Many countries follow the lockdown formula and it is causing great economic downslide. Some countries detest lock down. In some countries, "Herd Immunity" concept is promoted to overcome the disease and to save the country from economic disaster. Some countries address COVID-19 by enhancing medical testing and treating positive cases on certain protocols. A few nations follow masking and social distancing as a measure to contain COVID-19. Despite all the above methods, the simple protein coated RNA- COVID-19 is still spreading its ugly tentacles and lakhs of people all over the world have succumbed to this pandemic. All the

methods appear to be scientifically convincing yet, the containment of the virus appears to be an insurmountable task. Many economists predict fall in agriculture production, resultant food shortage, starvation. Unemployment due to industrial shut-down, lay off due to closing down of offices and establishments are also the visible ill-effects of the pandemic. The list is endless and the entire humanity is caught in Protagoras paradox and all the slokas are unable to hem the viral breach.

Every problem needs a solution and we need one for this pandemic. During the plague of 1665 to 1666, Sir Issac Newton while in isolation invented calculus and later discovered gravity. During this 2020 great lockdown and economic standstill it will be better if world leaders and economist, scientists focus their attention as one world to overcome this pandemic, save the humanity and halt the economic melt-down. They have to find ways and means to secure and safeguard the humanity from future catastrophe of this kind.

[**41**] Human beings have to redefine their role in the cycle of nature. To believe that human beings are the dominant amongst all living species, fauna and flora, animals, mammals, bacteria, unicellular & multicellular organisms etc. appears to be a misconception. Homo sapiens though a dominant species, cannot claim predominance as one specie is interlinked to the other in their own cycle of life. It has to co-exist within limits thereby maintaining the balance in nature. The indiscriminate population fuelled

deforestation and unnecessary animal human contact appears to be the cause of the present pandemic which could have been otherwise avoided.

[**42**] The impact of deforestation and the need to restore the destroyed forests is an issue that is applicable not only to the State of Manipur but it applies to the whole of the India and to other countries across the globe. The deforestation has affected the great Amazon forest of South America and other forests of the South American continent, the Congo Forest of Africa and other forest in the African continent, the various tropical and sub-tropical forests of Asian countries, the four seasonal forests of America, Canada, Europe, Russia and China to name a few. All these forests are impacted due to economy driven human activities. In the present crisis, there is a need for all the nations to come together and protect the forests and restore the lost forests. This will, in turn, save the ecology, environment and the planet.

[**43**] In the light of the above scientific data which clearly established that deforestation coupled with wild animal-human contact as a major cause of diseases, this Court is inclined to direct the State of Manipur, more particularly, the respondents No.1 to 5 to safeguard the forests, environment and ecology on the following parameters :

i) to take immediate measures to arrest wild fires which appear to be man made in many cases;

ii) to arrest the illegal encroachment of forest areas for human habitations;

iii) to protect wild animals, birds, flora and fauna as provided under the Acts and Rules;

iv) to take up afforestation of lands which have been subjected to deforestation by various means including forest fires;

v) boundary marking of forest areas by warning signs and monitoring in such manner as to avoid human contact with the wild animals, birds, flora and fauna other than for scientific research and studies. The direction as above applies subject to exceptions as made applicable under the Acts and Rules.

vi) respondents No. 1 to 5 will take up measures to educate people living nearby forests the need to protect the forests. This can be done by appropriate education tools and forest study camps. It should be made as a part of school subject with practical classes using audio-visual media. The officials of Public Health Department, Medical Department like Virologist, infectious disease specialist, officers of the forest department should work together on a common cause and identify the key areas of wild animal-human being contact. There should be regular screening to identify and isolate zoonotic virus transmission. They should also hold health camps on regular basis to identify and pick-up any new viral or bacterial disease.

(vii) the Union of India/respondent No. 6 may ensure that ongoing research on infectious diseases is properly funded and monitored. The University Grants Commission sanctions huge amount for education, research and faculty development to encourage young students in the field of science, arts, medicine, etc., to excel. The funding will have great impact on research and education and if not properly utilised, it will not serve the purpose in the field of science and medicine which is now grappling with many infectious diseases. It is desirable that the Central Government monitors the fund utilisation with accountability and proper audit. The feedback from students and research scholars may also help in monitoring the proper utilisation of funds. This suggestion is based on the grim warning expressed by the author, Charles Schmidt in the article **"For Experts Who Study Coronaviruses, a Grim Vindication."**

[**44**] The issue that has been addressed in this Public Interest Litigation has national and transnational impact. It is not possible to restore the forest ecology and environment, unless united action is taken to save nature and environment. To address the issue of deforestation and restoration of forests in the entire nation, several orders have been passed by the Hon'ble Supreme Court in the **T.N. Godavarman Thirumulpad vs Union Of India & Ors (supra)**. The issue addressed in the present order, if found relevant for other States, will have to be considered by the Hon'ble Apex Court at the appropriate stage or when the issue arises.

[**45**] Pursuant to the directions of the Hon'ble Supreme Court of India in **T.N. Godavarman Thirumulpad vs Union of India & Ors** : **(2006) 10 SCC 486**, the Compensatory Afforestation Fund Management and Planning Authority (CAMPA) was set up at the Centre and in the States. By 2019, the funds collected by CAMPA reportedly exceeded Rs. 1 lakh crores. In August 2019, CAMPA released Rs. 47436.18 crores to 27 States including Rs. 309.76 crores to the State of Manipur. Further, while announcing the stimulus package in May 2020, for combating the impact of COVID19 on the economy, the Hon'ble Finance Minister has earmarked a further sum of Rs. 6000 crores from out of CAMPA funds for creating job opportunities in rural and semi-urban areas. Thus there can be no dearth of funds for carrying on afforestation activities. It would appear that there is probably a further sum of Rs. 50,000 crores to be put to good use. The need of the hour is to only formulate appropriate schemes and to spend the funds raised till now and those that will come into this kitty in future in a judicious manner to achieve the forest cover of 33% of the total geographical area which is envisaged in the national forest policy and thereby restore the ecology and save the environment.

Respondent No. 1 is directed to submit a report on the utilisation of the above stated amount for the purpose of which the amount has been granted by the Government of India. The utilisation of this amount for afforestation and other forest related activities to be submitted with breakup details of utilisation of fund.

Reference made to Reserved Forests of Manipur, Scientific Papers and Court Orders in this order are set out as Annexures to this Order :

Sl. No.	Annexure	Subject	Page
1.	Annexure-A	List of Reserved Forests and Protected Forests of Manipur	48-49
2.	Annexure-B	"How Forest Loss Is Leading To a Rise in Human Disease," by Jim Robbins	50-55
3.	Annexure-C	"Forests and emerging infectious diseases of humans," by Bruce A. Wilcox and Brett Ellis	56-65
4.	Annexure-D	"Global Shifts in mammalian population trends reveal key predictors of virus spillover risk," by Chirstine K. Johnson, Peta L. Hitchens, Pranav S. Pandit, Julie Rushmore Tierra Smiley Evans, Cristin C. W. Young and Megan M. Doyle	66-75
5.	Annexure-E	Order dated 27.02.2014 passed by the Madras High Court in WP(MD) No. 3633 of 2014	76-78
6.	Annexure-F	Order dated 10.08.2015 passed by the Madras High Court in WP(MD) No. 3633 of 2014	79-91
7.	Annexure-G	Order dated 26.10.2015 passed by the Madras High Court in WP(MD) No. 3633 of 2014	92-94
8.	Annexure-H	For Experts Who Study Coronaviruses, a Grim Vindication, by Charles Schmidt	95-105

List the matter again on 12.06.2020.

JUDGE **CHIEF JUSTICE**

FR/NFR

Sandeep

[ANNEXURE-A]

CONTENTS

2020.06.03 14:23

[ANNEXURE-B]

Yale Environment 360

An area of forest in Indonesia that was cleared to make way for an oil palm plantation. CHAIDEER MAHYUDDIN/AFP/GETTY IMAGES

DEFORESTATION

How Forest Loss Is Leading To a Rise in Human Disease

A growing body of scientific evidence shows that the felling of tropical forests creates optimal conditions for the spread of mosquito-borne scourges, including malaria and dengue. Primates and other animals are also spreading disease from cleared forests to people.

BY JIM ROBBINS · FEBRUARY 23, 2016

In Borneo, an island shared by Indonesia and Malaysia, some of the world's oldest tropical forests are being cut down and replaced with oil palm plantations at a breakneck pace. Wiping forests high in biodiversity off the land for monoculture plantations causes numerous environmental problems, from the destruction of wildlife habitat to the rapid release of stored carbon, which contributes to global warming.

But deforestation is having another worrisome effect: an increase in the spread of life-threatening diseases such as malaria and dengue fever. For a host of ecological reasons, the loss of forest can act as an incubator for insect-borne and other infectious diseases that afflict humans. The most recent example came to light this month in the *Journal of Emerging Infectious Diseases*, with researchers documenting a steep rise in human malaria cases in a region of Malaysian Borneo undergoing rapid deforestation.

This form of the disease was once found mainly in primates called macaques, and scientists from the London School of Tropical Medicine and Hygiene wondered why there was a sudden spike in human cases. Studying satellite maps of where forest was being cut down and where it was left standing, the researchers compared the patchwork to the locations of recent malaria outbreaks. They realized the primates were concentrating in the remaining fragments of forest habitat, possibly increasing disease transmission among their own populations. Then, as humans worked on the new palm plantations, near the recently created forest edges, mosquitoes that thrived in this new habitat carried the disease from macaques to people.

Such phenomena are not uncommon. "In years when there is a lot of land clearance you get a spike in leptospirosis [a potentially fatal bacterial disease] cases, and in malaria and dengue," says Peter Daszak, the president of Ecohealth Alliance, which is part of a global effort to understand and ameliorate these dynamics. "Deforestation creates ideal habitat for some diseases."

The Borneo malaria study is the latest piece of a growing body of scientific evidence showing how cutting down large swaths of forests is a major factor in a serious human health problem – the outbreak of some of the world's most serious infectious diseases that emerge from wildlife and insects in forests. Some 60 percent of the diseases that affect people spend part of their life cycle in wild and domestic animals.

The research work is urgent – land development is rapidly taking place across regions with high biodiversity, and the greater the number of species, the greater the number of diseases, scientists say. They are deeply concerned that the next global pandemic could come out of the forest and spread quickly around the world, as was the case with SARS and Ebola, which both emerged from wild animals.

Mosquitoes are not the only carriers of pathogens from the wild to humans. Bats, primates, and even snails can carry disease, and transmission dynamics change for all of these species following forest clearing, often creating a much greater threat to people.

> The risk of disease outbreaks can be greatly magnified after forests are cleared for agriculture and roads.

Throughout human history pathogens have emerged from forests. The Zika virus, for example, which is believed to be causing microencephaly, or smaller than normal heads, in newborns in Latin America, emerged from the Zika forest of Uganda in the 1940s. Dengue, Chikungunya, yellow fever, and some other mosquito-borne pathogens likely also came out of the forests of Africa.

Forests contain numerous pathogens that have been passed back and forth between mosquitoes and mammals for ages. Because they evolved together, these viruses often cause few or no symptoms in their hosts, providing "a protective effect from a homegrown infection," says Richard Pollack of the T.H. Chan School Public Health at Harvard. But humans often have no such protection.

What research is demonstrating is that because of a complex chain of ecological changes, the risk of disease outbreaks, especially those carried by some mosquitoes, can be greatly magnified after forests are cleared for agriculture and roads.

A flood of sunlight pouring onto the once-shady forest floor, for example, increases water temperatures, which can aid mosquito breeding, explained Amy Vittor, an assistant professor of medicine at the University of Florida. She is an expert in the ecology of deforestation and malaria, which is where this dynamic is best understood.

Deforestation creates other conditions conducive to mosquito breeding. Leaves that once made streams and ponds high in tannins disappear, which lowers the acidity and makes the water more turbid, both of which favor the breeding of some species of mosquito over others. Flowing water is dammed up, deliberately and inadvertently, and pools. Because it is no longer taken up and transpired by trees, the water table rises closer to the forest floor, which can create more swampy areas.

As agriculture replaces forest, "re-growth of low lying vegetation provides a much more suitable environment" for the mosquitoes that carry the malaria parasite, Vittor says.

A man sleeps inside a mosquito net in his home in West Papua, Indonesia. ULET IFANSASTI/GETTY IMAGES

The link between deforestation and increases in malaria has been known for some time, but research in the last two decades has filled in many of the details. Much of the work has been done in Peru, where in one region in the 1990s cases of malaria went from 600 per year to 120,000, just after a road was built into virgin forest and people began clearing land for farms.

The cascade of human-induced ecological changes dramatically reduces mosquito diversity. "The species that survive and become dominant, for reasons that are not well understood, almost always transmit malaria better than the species that had been most abundant in the intact forests," write Eric Chivian and Aaron Bernstein, public health experts at Harvard Medical School, in their book *How Our Health Depends on Biodiversity*. "This has been observed essentially everywhere malaria occurs."

Mosquitoes can adapt fairly quickly to environmental change. In response to a push to use bed nets to prevent nighttime bites in malaria-prone regions of the world, for example, researchers are seeing a change in the time of day mosquitoes bite – many now target their human quarry in the hours before bed.

A study by Vittor and others found that one malaria-carrying mosquito species, *Anopheles darlingi*, in a deforested area in Peru was radically different than its cousins in intact forests; the *Anopheles darlingi* in deforested areas bit 278 times more frequently than in an intact forest, according to a study published in the *American Journal of Tropical Medicine and Hygiene* in 2006.

"In the forest, we found almost no breeding whatsoever, and no biting by the adult mosquitoes," Vittor said. That's probably because the ecology of the deforested landscape – short vegetation and deep water – favored their breeding, and they need human blood to grow their eggs.

The types of mosquitoes that do well in this radically altered ecosystem are more "vector competent," which means their systems are particularly good at manufacturing a lot of the pathogen that causes malaria. A study in Brazil, published in the *Journal of Emerging Infectious Diseases* in 2010, found that clearing four percent of the forest resulted in a nearly 50-percent increase in human malaria cases.

The ecology of the viruses in deforested areas is different. As forests are cut down, numerous new boundaries, or edges, are created between deforested areas and forest. A mosquito called *Aedes africanus*, a host of the yellow fever and Chikungaya viruses, often lives in this edge habitat and bites people working or living nearby. Other primates, which are also reservoirs for the pathogens, gather in the borders of these different ecosystems, providing an ongoing source of virus for the insects.

Insects are not the only way that deforestation can exacerbate infectious diseases. For some unknown reason, the species of snails that can better adapt to warm open areas that occur after a forest is cut down are better hosts for parasites called flatworms, some of which cause schistosomiasis, a disease which damages human organs.

Scientists are concerned that these outbreaks exacerbated by human alteration of landscapes could cause the next pandemic. The Roman Empire once stretched from Scotland to Africa and lasted for more than 400 years. No one knows exactly why the empire collapsed, but one contributing factor may have been malaria. A mass grave of babies from that era, excavated in the 1990s, found, through DNA analysis, that many of them had died from malaria, according to a study published in 2001 in the journal *Ancient Biomolecules*. Some researchers speculate that the malaria outbreak may have been exacerbated by deforestation in Rome's surrounding Tiber River Valley to supply timber to the growing city.

> One piece of the puzzle is to know what pathogens might come out of the forest in the future.

Once a disease has left a forested region, it can travel in human beings, crossing the world in a matter of hours by airplane before the person even shows symptoms. How well it does in its new homes depends on several factors. Once Zika traveled to Brazil from Africa, for example, it flourished because *Aedes aegypti* mosquitoes hang out around people and love to lay their eggs in small containers of water. Many people in Brazil's large slums store water in buckets, and standing water also collects in tarps, old tires, and trash.

A key question about the Zika virus is whether it will enter the primate populations in South America, which means it might become a permanent resident and an ongoing source of infection. "Is it going to set up shop there?" asks Vittor. "We don't know."

Mosquitoes aren't the only creatures that bring fever out of the forest. Angolan free-tailed bats were believed to harbor the Ebola virus that broke out and killed more than 11,000 people last year. And AIDS, which has killed more than 25 million people worldwide, came from people eating bush meat, likely chimpanzees.

A wild card in this disease scenario is the rapidly changing climate. If spring comes early, mosquitoes hatch earlier and summer populations are larger. In Southeast Asia, the spike in temperatures during El Niño weather cycles correlates with dengue fever outbreaks, because the warmer weather allows mosquitoes to breed faster and expand the population, which spreads the virus further, according to a study last year in the *Proceedings of the National Academy of Sciences.*

Part of the solution is to recognize and understand these connections and teach people that keeping nature intact has protective effects. And where people do cut down forests or build roads, numerous steps can be taken to lessen the chance of mosquito-borne disease outbreaks – education campaigns, more clinics, health training, and medical monitoring.

Another piece of the puzzle is to know what pathogens the world might be up against in the future as they come out of the forest. Ecohealth Alliance is cataloging wildlife-borne viruses in wild places where there is new encroachment into undisturbed nature and health care is poor or non-existent. The goal is to better understand how these viruses might spread and to potentially develop vaccines.

"If we could deal with the trade in wildlife and deforestation we wouldn't need to stop an outbreak," like Zika or Ebola, said Daszak, the organization's president. "We would have already dealt with it."

Jim Robbins is a veteran journalist based in Helena, Montana. He has written for the *New York Times*, *Conde Nast Traveler*, and numerous other publications. His latest book is the *The Wonder of Birds: What they Tell Us about the World, Ourselves and a Better Future*. MORE →

[ANNEXURE-C]

Forests and emerging infectious diseases of humans

B.A. Wilcox and B. Ellis

Bruce A. Wilcox and **Brett Ellis** are with the Center for Infectious Disease Ecology in the Asia-Pacific Institute for Tropical Medicine and Infectious Diseases, University of Hawaii at Manoa, United States.

With the interweaving of forests, pathogens and the development of human civilization, deforestation and other land use changes have an important part in the emergence of disease.

Infectious diseases have always been an important part of human life. They have significantly influenced human biology and society, even determining the course of major historical events.
Infectious diseases can be viewed ecologically as an extension of host–parasite relationships. They are as much a part of any ecosystem as predator–prey or plant–herbivore relationships. In fact, disease-causing viruses, bacteria and protozoans are commonly and collectively referred to as "microparasites" in infectious disease epidemiology. Moreover, infection by a microparasite is not inevitably a disease-causing event. Most often, host and microparasite coexist peacefully, because highly pathogenic genotypes that eliminate the host are selected against, as are susceptible hosts lacking acquired or native immunity (inherited resistance). Thus disease emergence is a transient phenomenon in a human population, and in its most severe form is typically a consequence of rapid social and environmental change or instability.

The first plague-causing pathogens such as smallpox are believed to have originated in tropical Asia early in the history of animal husbandry and large-scale forest clearing for permanent cropland and human settlements (McNeil, 1976). Crowding and the mixing of people, domestic animals and wildlife, along with a warm humid climate, were as ideal for pathogen evolution, survival and transmission several millennia ago as they are now.

The concept of emerging infectious diseases (EIDs) was prompted by the appearance of novel pathogens such as human immunodeficiency virus (HIV) and Ebola virus; the evolution of more virulent or drug-resistant pathogenic variants of known microbes; and the geographic expansion and increasing epidemic outbreaks of the diseases caused by these pathogens as well as older diseases such as malaria and dengue. More recently, the concept was reinforced by the dramatic outbreak of severe acute respiratory syndrome (SARS) virus.

The recent upsurge in infectious diseases, which began to attract the attention of the World Health Organization (WHO) and leading national health agencies in the 1980s, is often attributed to the dramatic increase in human population size and mobility, as well as social and environmental changes since the Second World War. Actually, such transitions have caused major upsurges in infectious diseases at the regional level since antiquity. The most notable difference today is the speed, scale and global dimension of the transition, and its occurrence in the era of modern biomedicine and public health programmes. Overconfidence in the former and inadequate deployment of the latter are major contributors to the EID problem, especially in the tropical developing regions.

An increasing number of studies on EIDs point to changes in land cover and land use, including forest cover change (particularly deforestation and forest fragmentation) along with urbanization and agricultural intensification, as major factors contributing to the surge in infectious diseases. Indeed the current increase coincides with accelerating rates of tropical deforestation in the past several decades. Today, both deforestation and emerging infectious diseases remain largely associated with tropical regions but have impacts that extend globally. Both are similarly intertwined with issues of economic development, land use and governance, requiring cross-sectoral solutions.

This article provides an overview of the role of forests and deforestation in EIDs. It highlights the most prominent forest-associated diseases and briefly describes the current state of understanding of the mechanisms by which forest conversion and alteration contribute to EIDs. Finally, it identifies forest resource management measures required to mitigate the EID problem.

Expansion into the forest, involving more frequent contact with wildlife, exposes humans to pathogens that are foreign to them and is a frequent cause of disease outbreaks – for example yellow fever in the case of this forest-adjacent settlement in Kenya

B. Ellis

Examples of forest-associated emerging infectious diseases

Agent/disease	Distribution	Hosts and/or reservoirs	Exposure	Possible emergence mechanisms
Viruses				
Yellow fever	Africa South America	Non-human primates	Vector	Deforestation and expansion of settlements along forest edges Hunting Water and wood collection Domestication of vectors and pathogen
Dengue	Pantropical	Non-human primates	Vector	Mosquito vector and pathogen adaptation Urbanization and ineffective vector control programmes
Chikungunya	Africa Indian Ocean Southeast Asia	Non-human primates	Vector	Pathogen and vector domestication
Oropouche	South America	Non-human primates Others	Vector	Forest travel Vector composition changes
SIV	Pantropical	Non-human primates	Direct	Deforestation and human expansion into forest Hunting and butchering of forest wildlife Pathogen adaptation
Ebola	Africa	Non-human primates Bats	Direct	Hunting and butchering Logging Outbreaks along forest fringes Agriculture Alteration of natural fauna

Nipah virus	South Asia	Bats Pigs	Direct	Pig and fruit production on forest border
SARS	Southeast Asia	Bats Civets	Direct	Harvesting, marketing and mixing of bats and civet cats Wildlife trade for human consumption
Rabies	Worldwide	Canines Bats Other wildlife	Direct	Human expansion into forest
Rocky Mountain spotted fever	North America	Invertebrate ticks	Vector	Human expansion into forest Forest recreation
Protozoa				
Malaria	Africa Southeast Asia South America	Non-human primates	Vector	Deforestation, habitat alteration beneficial for mosquito breeding Human expansion into forest, non-human primate malaria among humans
Leishmaniasis	South America	Numerous mammals	Vector	Human expansion into forest Domestication of zoophilic vectors Habitat alteration, habitation building near forest edge Deforestation Domestication of zoonotic cycles by non-immune workers
Sleeping sickness	West and Central Africa	Humans	Vector	Human expansion into forest, disease incidence associated with forest edge
Bacteria				
Babesiosis	North America Europe	Humans Wildlife	Vector	Disease often found among ticks in forested areas
Lyme disease	Worldwide	Humans Deer Mice	Vector	Possible association with deforestation and habitat fragmentation Forest workers at increased risk of disease
Leptospirosis	Worldwide	Rodents	Indirect	Watershed alteration and flooding
Helminth				
Eccinococcus multiocularis	Northern Hemisphere	Foxes Rodents Small mammals	Direct	Deforestation Increase in rodent and fox hosts Pathogen spillover to dogs Human expansion into forest, exposure of susceptible population

ASSOCIATION OF EMERGING INFECTIOUS DISEASES WITH FORESTS

In all, about three-fourths of recognized EIDs either once were, or currently are, zoonotic, i.e. transmitted between animals and humans (Taylor, Latham and Woolhouse, 2001). Not surprisingly, the ancestry of the pathogens causing these diseases can usually be traced to wildlife. Pathogens whose current emergence patterns show a direct association with forests (see Table for examples) represent about 15 percent of the approximately 250 EIDs (Despommier, Ellis and Wilcox, 2006). Some EIDs not currently associated with forests originated from a sylvatic cycle but have since "escaped" and are now solely maintained by human–human transmission or a human–vector–human cycle independent of forests. The two most prominent EIDs in this category are HIV and dengue, which broke free from their primate transmission cycles in African forests and eventually spread globally, two decades ago in the case of HIV and several centuries ago for dengue. Still other EIDs such as tuberculosis, hepatitis A/B/C/E/G, most sexually transmitted diseases, opportunistic infections of individuals who are immunocompromised (as a result of HIV, for example), and a growing number of infections caused by bacteria resistant to antimicrobial drugs are mainly attributable to dramatic social and ecological changes associated with the explosive rates of urban growth in recent decades.

For those EIDs currently associated with forests, the proximate causal factors in their emergence include a combination of deforestation and other land use changes, increased human contact with forest pathogens among populations lacking previous exposure, and pathogen adaptation. Many may be transmitted among non-human primate hosts or insect vectors, and involve a variety of potential intermediate hosts including domestic animals. Of most concern, following initial local emergence a number of these diseases have demonstrated the potential to spread regionally or globally and become a significant threat to humans, domestic animals and wildlife populations.
Although relatively few plant parasites or pathogens are known to infect animals, including humans, the impact of emerging plant diseases on plant populations is also an increasing concern. The problem of EIDs includes not only the impacts of diseases from forests, but also the impacts of disease on forests, including forest wildlife as well as vegetation (Ostfeld, Keesing and Eviner, 2006).

Forests or deforestation *per se* are not the cause of either forest-associated infectious disease emergence or the globally increasing EID trend overall; EID causality is more complex than this. The main driver is the exponential growth in population, consumption and waste generation of the past several decades, which has driven the combination of urbanization, agricultural expansion and intensification, and forest habitat alteration that results in regional environmental change (see Box). The disease emergence process typically appears to be associated with a combination of these environmental factors. But the common factor is change – relatively abrupt or episodic social and ecological change. Most often this is reflected in changes in land cover and land use (unplanned urbanization and land use conversion), agricultural intensification (dams, irrigation projects, factory farms, etc.) and displacement and migration of people.

Episodic population migration and resettlement, associated with road building and the opening up of new transportation routes along with forest clearing and fragmentation, can be described as local or regional drivers of disease emergence. Such changes, particularly when unplanned and a result of political or economic instability or even military conflict in some cases, can have catastrophic consequences. The prime example is AIDS, which originated in tropical forest (Sharp *et al.*, 2001) and expanded throughout a region that was undergoing such changes and lacked public health infrastructure, including systems of disease surveillance and control.

Like AIDS, most forest-originating EIDs are caused by viruses, although others are caused by bacteria, protozoans, helminths (worms) and fungi. These diseases are frequently not research priorities until they have become a threat to affluent populations, so knowledge about their distribution and biology is very limited in most cases. The historical orientation of tropical medicine towards understanding disease natural history and ecology was, unfortunately, abandoned with the advent of modern biomedicine and the mistaken belief that infectious diseases had been conquered by science (Gubler, 2001). Today's biggest research challenge is posed by the disciplinary gaps between infectious disease researchers, wildlife experts, ecologists and social scientists. The problems are of course compounded by the increasing numbers and densities of poor people living without potable water, sanitation and adequate public health infrastructure in developing countries.

Forest zoonotic and vector-transmitted diseases

Yellow fever is the most well-studied disease from the standpoint of its association with forests (Monath, 1994). The virus that causes yellow fever is maintained in a transmission cycle of arboreal monkeys and sylvatic mosquitoes. Expansion into the forest by human settlements is a frequent cause of outbreaks. For example, the first outbreak of yellow fever in Kenya (1992 to 1993) involved a settlement where cases were limited to people collecting fuelwood and water, or possibly hunting in the forest. Much larger outbreaks occur when the transmission cycle leaves the forest canopy and extends to peri-urban and urban areas where the much higher density of humans and mosquitoes can fuel large epidemics (Sang and Dunster, 2001). This occurred in the

Sudan in 2005, probably exacerbated by people fleeing areas of armed conflict and soldiers returning from forested areas. Environmental factors including abnormal rainfall may also have contributed to spreading the disease. The evolutionary capacity for rapid adaptation enables viruses to be transmitted efficiently in domestic or peri-domestic cycles.

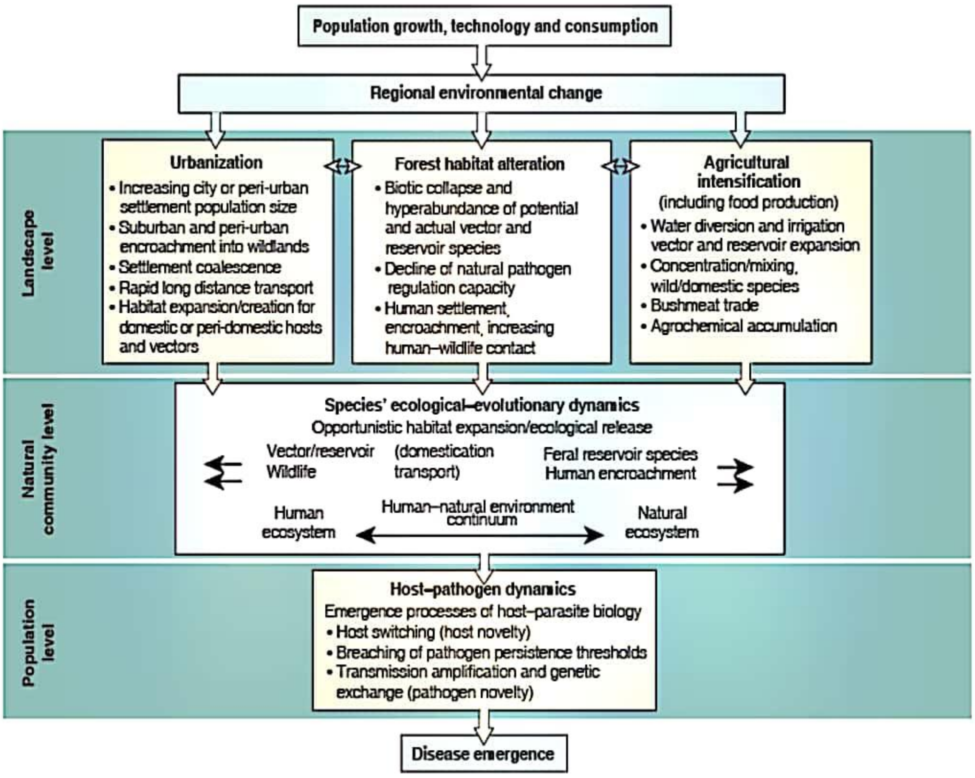
Dengue haemorrhagic fever, caused by a type of dengue virus, is very similar to yellow fever in its ecology, at least historically (Monath, 1994). Originating as a sylvatic disease with a similar set of primate hosts, mosquito vectors and niche, it acquired a domestic cycle at least several centuries ago. It has recently developed into one of the world's most rapidly emerging diseases, infecting as many as 50 million to 100 million people annually (Holmes and Twiddy, 2003). The key to dengue's success as a pathogen is believed to be its adaptation to the domestic mosquito *Aedes aegypti*, which has allowed it to become endemic in an increasing number of cities and surrounding peri-urban areas, particularly in Asia and Latin America (Moncayo *et al.*, 2004).

Malaria, a much older disease which contributes by far to the greatest number of deaths and disability of any infectious disease (300 million to 500 million cases annually, with a death toll as high as 2.7 million), has less definitive zoonotic origins (Mu *et al.*, 2005). It is nonetheless transmitted in many areas by forest-associated mosquitoes. Recent research suggests that increased disease incidence in some areas of Africa, South America and Southeast Asia is linked to deforestation (Vittor *et al.*, 2006; Walsh, Molyneux and Birley, 1993). Road building, tree felling, reduced shade and increased pooling of water have been shown to promote breeding and more rapid development of mosquito larvae (Afrane *et al.*, 2005; de Castro *et al.*, 2006). Of additional concern, a form of malaria previously found in non-human primates has recently been found in humans in Southeast Asia (Jongwutiwes *et al.*, 2004; Singh *et al.*, 2004).

A number of other noteworthy forest-associated zoonotic EIDs do not appear to involve mosquitoes as vectors although their transmission cycles are not yet entirely certain. These include chikungunya, Oropouche virus, Ebola and simian immunodeficiency virus (SIV). The dramatic consequences of Ebola and SIV emergence have been evidenced over recent decades. HIV is a zoonotic SIV. SIVs have recently been found to be common in Old World monkeys (Galat and Galat-Luong, 1997). The hunting, butchering or illegal procurement of these animals not only is a major concern for conservation but also increases the risk of disease emergence (Wolfe *et al.*, 2005).

Many of the Ebola outbreaks have occurred in forest fringe areas, where expansion of human populations is bringing them into contact with pathogens that are foreign to them, particularly through more frequent contact with wildlife. This has led to a hypothesis that mechanisms associated with agricultural land use changes bordering forests and changes in the natural fauna may be involved in emergence (Morvan *et al.*, 2000; Patz *et al.*, 2004). Recently, it has also been suggested that bats may serve as the reservoir for Ebola and that monkeys may contract the disease much as humans do (Leroy *et al.*, 2005). Fruit bats are also important hosts of additional EIDs including Nipah and SARS viruses (Field *et al.*, 2001; Lau *et al.*, 2005).

Casual schema of infectious disease ecology



The combination of increasing population and resource consumption, along with waste generation, drives the regional environmental change typically indicated by trends in land use and land cover change. Although the pattern of change varies from region to region, three characteristic processes occur in relation to land use: urbanization, agricultural intensification (including food production and distribution) and alteration of forest habitat.

The three categories of land use – urban, agricultural and natural habitat – represent an ecosystem continuum along a gradient from domestic to natural (left to right in the diagram). Three ecological trends are associated with these changes: vector and reservoir domestication (or peri-domestication); invasion of domestic habitat by opportunistic wildlife such as some rodents and blood-sucking arthropods (mosquitoes, ticks, midges and others); and invasion of the natural habitat by feral species such as domestic pigs, goats, rats, mice, dogs and cats. These species become pathogen reservoirs particularly in disturbed and fragmented forest adjacent to settlements. The convergence of human and animal hosts and reservoir and vector species within ecosystems, and the movement, shifting and mixing across the ecosystem continuum affects host–pathogen dynamics in a manner that facilitates disease emergence, as follows:

- pathogens have increased opportunities for host switching (including adaptation to a new host);
- transmission is amplified and the opportunity for more rapid evolution is increased with multiple, interacting transmission cycles;
- pathogens' rate of infection exceeds the threshold required to produce an epidemic or an endemic disease owing to unprecedented population densities of the vector, the reservoir and susceptible human populations;
- pathogens evolve increased pathogenicity, infectivity and ability to avoid immune system detection, owing to increased opportunities for interaction of endemic infection cycles and pathogen strains, and greater density and genetic variability of pathogen populations.

Sources: Wilcox and Colwell, 2005; Wilcox and Gubler, 2005.

Water-borne diseases

Another category of infectious diseases – indirectly associated with forests or forest land management – is water-borne. Their natural cycles may or may not involve forest wildlife, but their transmission (both among their animal hosts and to humans) is facilitated by altered surface water quality and regimes, which may be influenced by upland deforestation and poor watershed management (including overgrazing, removal of riparian vegetation and stream channellization). Water-borne pathogens include the enteric viruses rotavirus and norovirus and the bacteria *Campylobacter* spp. and Vibrio cholerae, which collectively cause millions of deaths annually, particularly among infants. *Vibrio cholerae*, which lives symbiotically (in mutually beneficial relationship) with marine and estuarine crustaceans, is responsible for an estimated 1 to 2 million cholera cases annually (WHO, 2006). All these pathogens are found in inland as well as coastal surface waters, especially (but not only) water contaminated with human or animal excrement. Other widespread water-borne EIDs include protozoans of the genera *Cryptosporidium* and *Giardia*, which along with *Campylobacter* spp. are maintained by wild and feral ungulates. These pathogens, along with leptospirosis, one of the world's most widespread zoonotic EIDs for which virtually all mammal species are natural or accidental hosts, are often associated with ecologically disturbed forested watersheds supporting high densities of pigs and rats. Epidemics of leptospirosis have been occurring with increased frequency globally in flood-prone rural and urban areas with poor drainage and sanitation, conditions commonly found in impoverished urban, peri-urban and rural environments throughout the developed and developing world (Vinetz *et al.*, 2005; Wilcox and Colwell, 2005).

MECHANISMS OF HUMAN PATHOGEN EMERGENCE

The role of forests and forest management in the emergence of infectious diseases of humans appears to involve three separate but interacting dynamics:

- land use change and expansion of human populations into forest areas, resulting in exposure of immunologically naïve human and domestic animal populations (i.e. those lacking previous experience with the microparasite fauna) to pathogens occurring naturally in wildlife;
- forest clearing and alteration producing an increase in the abundance or dispersal of pathogens by influencing host and vector abundance and distribution;
- alteration of ecohydrological functions such as infiltration, peak discharge and runoff which facilitate the survival and transport of water-borne pathogens in watersheds and catchment basins.

These changes are often linked to forest clearing and increased edge habitat, with fragmentation of the forest landscape and disturbance of the vertical structure and diversity within the forest stands. The increase in the density of some pathogens' hosts and vectors effectively expands the pathogens' habitat and increases their infection prevalence in hosts. The increased number of hosts or vectors or both and their increased rate of infection not only increase the frequency of their contact with humans, but also the likelihood of the host or vector being infectious. Most importantly, it allows the pathogen to persist indefinitely and the disease to become endemic.

One of the best documented cases of this process concerns Lyme disease, an EID caused by a pan-temperate tick-borne spirochete bacteria of the genus *Borrellia*. The ecology of its emergence in the northeastern United States, studied in great detail, has implications regarding the role of forest management in disease generally (Allan, Keesing and Ostfeld, 2003). Lyme disease involves a complex sylvatic cycle in which the vector prefers different animal host species during different stages of its life cycle. The most important factor determining pathogen abundance appears to be the abundance of two animal species that proliferate in fragmented forest landscapes: white-footed mice, which act as pathogen "superspreaders", and white-tailed deer, the optimal adult tick host. These species are adapted to forest edges, and they have fewer predators in these landscapes than in unfragmented forest blocks. Moreover, the less diverse community of vertebrates in fragmented forests results in higher overall pathogen transmission rates, since white-footed mice are among the most successful vertebrate hosts for this microparasite.

The finding that intact forest vertebrate communities provide a pathogen dilution effect, together with the well-known role of predators in regulating rodents and ungulate populations in healthy ecosystems, has prompted some ecologists to categorize regulation of pathogen emergence as a forest ecosystem service. The ecohydrological functions of healthy upland forests and watersheds can be said to have a similar role, regulating water-borne pathogen emergence by "capturing" and filtering pathogen-laden runoff and modulating the amplitude of peak flows during seasonal storms. The loss of these functions facilitates pathogen transmission and maintenance in host populations, increasing the amount of human pathogens contained in animal excreta. Epidemics of cholera and leptospirosis frequently occur following exposure of large numbers of people to the pathogens mobilized from soil and sediments and suspended in the flood waters (Wilcox and Colwell, 2005).

Forest fragmentation affects disease dynamics by influencing host and vector abundance and distribution and thus the abundance or dispersal of pathogens

www.forestryimages.org/4166001/J.D. Ward/USDA Forest Service

CONCLUSION

Emerging infectious diseases are considered to be among today's major challenges to science, global health and human development. Rapid changes associated with globalization, especially the rapidly increasing ease of transport, are mixing people, domestic animals, wildlife and plants, along with their parasites and pathogens, at a frequency and in combinations that are unprecedented.

The role of and potential effects on forests and implications for forest resource management are significant. Forest land use changes and practices, particularly when unregulated and unplanned, frequently lead to increased prevalence of zoonotic and vector-borne diseases, and occasionally boost the prevalence of diseases capable of producing catastrophic pandemics. This should be a consideration in forest land use and forest resource planning and management.

In view of the enormous impact EIDs have on humans and economic development, including the economic impacts of diseases on agriculture and forestry, collaboration between the agricultural, forest and public health sectors is required to develop policies and practices for the prevention and control of EIDs. This will require substantial increases in the regulation, surveillance and screening of pathogens in transportation systems.

Research on EIDs, particularly that involving the ecological epidemiology of zoonotic and vector-borne diseases associated with forests, needs to be integrated with forest resource management and planning. Greater emphasis is needed on integrating research and practice, for example through the development of forest management guidelines that can contribute to the control and prevention of EIDs. This will require increased interdisciplinary and collaborative research among foresters, forest ecologists, and wildlife and human infectious disease experts for better understanding of the role and impact of forests and forest land use and management on EIDs.

Bibliography

Afrane, Y.A., Lawson, B.W., Githeko, A.K. & Yan, G. 2005. Effects of microclimatic changes caused by land use and land cover on duration of gonotrophic cycles of *Anopheles gambiae* (Diptera: Culicidae) in western Kenya highlands. *Journal of Medical Entomology*, 42(6): 974–980.

Allan, B.F., Keesing, F. & Ostfeld, R.S. 2003. Effect of forest fragmentation on Lyme disease risk. *Conservation Biology*, 17(1): 267–272.

de Castro, M.C., Monte-Mor, R.L., Sawyer, D.O. & Singer, B.H. 2006. Malaria risk on the Amazon frontier. *Proceedings of the National Academy of Sciences of the United States of America*, 103(7): 2452–2457.

Despommier, D., Ellis, B. & Wilcox, B.A. 2006. The role of ecotones in emerging infectious diseases. *EcoHealth*, 3 (In press).

Field, H., Young, P., Yob, J.M., Mills, J., Hall, L. & Mackenzie, J. 2001. The natural history of Hendra and Nipah viruses. *Microbes and Infection*, 3(4): 307–314.

Galat, G. & Galat-Luong, A. 1997. Virus transmission in the tropical environment, the socio-ecology of primates and the balance of ecosystems. *Santé*, 7(2): 81–87.

Gubler, D.J. 2001. Prevention and control of tropical diseases in the 21st century: back to the field. *American Journal of Tropical Medicine and Hygiene*, 65(1): v–xi.

Holmes, E.C. & Twiddy, S.S. 2003. The origin, emergence and evolutionary genetics of dengue virus. *Infection, Genetics and Evolution*, 3(1): 19–28.

Jongwutiwes, S., Putaporntip, C., Iwasaki, T., Sata, T. & Kanbara, H. 2004. Naturally acquired *Plasmodium knowlesi* malaria in human, Thailand. *Emerging Infectious Diseases*, 10(12): 2211–2213.

Lau, S.K, Woo, P.C., Li, K.S., Huang, Y., Tsoi, H.W., Wong, B.H., Wong, S.S., Leung, S.Y., Chan, K.H. & Yuen, K.Y. 2005. Severe acute respiratory syndrome coronavirus-like virus in Chinese horseshoe bats. *Proceedings of the National Academy of Sciences of the United States of America*, 102(39): 14040–14045.

Leroy, E.M., Kumulungui, B., Pourrut, X., Rouquet, P., Hassanin, A., Yaba, P., Délicat, A., Paweska, J.T., Gonzalez, J.P. & Swanepoel, R. 2005. Fruit bats as reservoirs of Ebola virus. *Nature*, 438(7068): 575–576.

McNeill, W.H. 1976. *Plagues and peoples*. Garden City, New York, USA, Anchor Press/Doubleday.

Monath, T.P. 1994. Yellow fever and dengue – the interactions of virus, vector and host in the re-emergence of epidemic disease. *Seminars in Virology*, 5(2): 133–145.

Moncayo, A.C., Fernandez, Z., Ortiz, D., Diallo, M., Sall, A., Hartman, S., Davis, C.T., Coffey, L., Mathiot, C.C., Tesh, R.B. & Weaver, S.C. 2004. Dengue emergence and adaptation to peridomestic mosquitoes. *Emerging Infectious Diseases*, 10(10): 1790–1796.

Morvan, J.M., Nakoune, E., Deubel, V. & Colyn, M. 2000. Ebola virus and forest ecosystems. *Bulletin de la Societé Pathologique Exotique*, 93(3): 172–175.

Mu, J., Joy, D.A., Duan, J., Huang, Y., Carlton, J., Walker, J., Barnwell, J., Beerli, P., Charleston, M.A., Pybus, O.G. & Su, X.Z. 2005. Host switch leads to emergence of *Plasmodium vivax* malaria in humans. *Molecular Biology and Evolution*, 22(8): 1686–1693.

Ostfeld, R.S., Keesing, F. & Eviner, V., eds. 2006. *Ecology of infectious disease: effects of ecosystems on disease and of disease on ecosystems.* Princeton, New Jersey, USA, Princeton University Press. (In press).

Patz, J.A., Daszak, P., Tabor, G.M., Aguirre, A.A., Pearl, M., Epstein, J., Wolfe, N.D., Kilpatrick, A.M., Foufopoulos, J., Molyneux, D. & Bradley, D.J. 2004. Unhealthy landscapes: policy recommendations on land use change and infectious disease emergence. *Environmental Health Perspectives*, 112(10): 1092–1098.

Sang, R.C. & Dunster, L.M. 2001. The growing threat of arbovirus transmission and outbreaks in Kenya: a review. *East African Medical Journal*, 78(12): 655–661.

Sharp, P.M., Bailes, E., Chaudhuri, R.R., Rodenburg, C.M., Santiago, M.O. & Hahn, B.H. 2001. The origins of acquired immune deficiency syndrome viruses: where and when? *Philosophical Transactions of the Royal Society of London, Series B, Biological Sciences*, 356: 867–876.

Singh, B., Kim Sung, L., Matusop, A., Radhakrishnan, A., Shamsul, S.S., Cox-Singh, J., Thomas, A. & Conway, D.J. 2004. A large focus of naturally acquired *Plasmodium knowlesi* infections in human beings. *Lancet*, 363(9414): 1017–1024.

Taylor, L.H., Latham, S.M. & Woolhouse, M.E. 2001. Risk factors for human disease emergence. *Philosophical Transactions of the Royal Society of London, Series B, Biological Sciences*, 356(1411): 983–989.

Vinetz, J.M., Wilcox, B.A., Aguirre, A., Gollin, L.X., Katz, A.R., Fujioka, R., Maly, K., Horwitz, P. & Chang, H. 2005. Beyond disciplinary boundaries: leptospirosis as a model of incorporating transdisciplinary approaches to understanding infectious disease emergence. *Ecohealth*, 2: 291–306.

Vittor, A.Y., Gilman, R.H., Tielsch, J., Glass, G., Shields, T., Lozano, W.S., Pinedo-Cancino, V. & Patz, J.A. 2006. The effect of deforestation on the human-biting rate of *Anopheles darlingi*, the primary vector of falciparum malaria in the Peruvian Amazon. *American Journal of Tropical Medicine and Hygiene*, 74(1): 3–11.

Walsh, J.F., Molyneux, D.H. & Birley, M.H. 1993. Deforestation: effects on vector-borne disease. *Parasitology*, 106(Suppl.): S55–S75.

Wilcox, B.A. & Colwell, R.R. 2005. Emerging and reemerging infectious diseases: biocomplexity as an interdisciplinary paradigm. *EcoHealth*, 2(4): 244–257.

Wilcox, B.A. & Gubler, D.J. 2005. Disease ecology and the global emergence of zoonotic pathogens. *Environmental Health and Preventive Medicine*, 10(5): 263–272.

Wolfe, N.D., Daszak, P., Kilpatrick, A.M. & Burke, D.S. 2005. Bushmeat hunting, deforestation, and prediction of zoonoses emergence. *Emerging Infectious Diseases*, 11(12): 1822–1827.

World Health Organization (WHO). 2006. *Cholera surveillance and number of cases*. Available at: www.who.int/topics/cholera/surveillance/en/index.html

[ANNEXURE-D]

PROCEEDINGS B

royalsocietypublishing.org/journal/rspb

Research

Check for updates

Cite this article: Johnson CK, Hitchens PL, Pandit PS, Rushmore J, Evans TS, Young CCW, Doyle MM. 2020 Global shifts in mammalian population trends reveal key predictors of virus spillover risk. *Proc. R. Soc. B* **287**: 20192736. http://dx.doi.org/10.1098/rspb.2019.2736

Received: 22 November 2019
Accepted: 13 March 2020

Subject Category:
Global change and conservation

Subject Areas:
ecology, health and disease and epidemiology

Keywords:
zoonotic disease, virus, spillover, threatened species, exploitation, habitat loss

Author for correspondence:
Christine K. Johnson
e-mail: ckjohnson@ucdavis.edu

Electronic supplementary material is available online at https://doi.org/10.6084/m9.figshare.c.4899876.

THE ROYAL SOCIETY
PUBLISHING

Global shifts in mammalian population trends reveal key predictors of virus spillover risk

Christine K. Johnson[1], Peta L. Hitchens[2], Pranav S. Pandit[1], Julie Rushmore[1], Tierra Smiley Evans[1], Cristin C. W. Young[1] and Megan M. Doyle[1]

[1]EpiCenter for Disease Dynamics, One Health Institute, School of Veterinary Medicine, University of California, Davis, CA 95616, USA
[2]Melbourne Veterinary School, Faculty of Veterinary and Agricultural Sciences, University of Melbourne, Werribee, VIC 3030, Australia

CKJ, 0000-0001-6673-8743; PLH, 0000-0002-7528-7056; PSP, 0000-0001-7649-0649; MMD, 0000-0002-3784-355X

Emerging infectious diseases in humans are frequently caused by pathogens originating from animal hosts, and zoonotic disease outbreaks present a major challenge to global health. To investigate drivers of virus spillover, we evaluated the number of viruses mammalian species have shared with humans. We discovered that the number of zoonotic viruses detected in mammalian species scales positively with global species abundance, suggesting that virus transmission risk has been highest from animal species that have increased in abundance and even expanded their range by adapting to human-dominated landscapes. Domesticated species, primates and bats were identified as having more zoonotic viruses than other species. Among threatened wildlife species, those with population reductions owing to exploitation and loss of habitat shared more viruses with humans. Exploitation of wildlife through hunting and trade facilitates close contact between wildlife and humans, and our findings provide further evidence that exploitation, as well as anthropogenic activities that have caused losses in wildlife habitat quality, have increased opportunities for animal–human interactions and facilitated zoonotic disease transmission. Our study provides new evidence for assessing spillover risk from mammalian species and highlights convergent processes whereby the causes of wildlife population declines have facilitated the transmission of animal viruses to humans.

1. Introduction

Infectious diseases that originate from animals and infect people comprise the majority of recurrent and emerging infectious disease threats and are widely considered to be one of the greatest challenges facing public health [1–3]. Characterization of pathogen transmission events from wildlife to humans remains an important scientific challenge hampered by pathogen detection limitations in wild species. Disease spillover is probably vastly under-reported, particularly in remote regions where people have limited access to healthcare. Zoonotic disease spillover events are also difficult to detect, especially if the disease spectrum includes mild or non-specific symptoms, or if there is limited to no human-to-human transmission. While the common characteristics of zoonotic diseases have advanced an understanding of disease transmission between animals and humans [4–7], efforts to date have been hampered by sparse data.

The synthesis of epidemiological and ecological profiles of viruses and their hosts has enabled the detection of intrinsic virus and host features linked to species propensity to share viruses with humans [5,8]. For example, host phylogenetic proximity to humans and increased urbanization within a host

Table 1. IUCN Red List status and population trend data combined to recategorize species according to conservation status as used for statistical analyses in this study, with number of terrestrial wild mammalian species in each category (*n*).

Red List status	population trend	conservation status	*n*
critically endangered	combined across all	critically endangered (CR)	193
endangered	combined across all	endangered (EN)	439
vulnerable	combined across all	vulnerable (VU)	493
near threatened	decreasing	near threatened decreasing	243
near threatened	stable	near threatened stable	12
near threatened	increasing	near threatened increasing	7
least concern	decreasing	least concern decreasing	391
least concern	stable	least concern stable	1281
least concern	increasing	least concern increasing	58
data deficient	combined across all	data deficient/unknown trend	790
least concern	unknown	data deficient/unknown trend	1371
near threatened	unknown	data deficient/unknown trend	57

distribution has been shown to be positively correlated with the number of zoonotic viruses in a species [5]. Zoonotic disease richness has also been linked to larger geographical range and more litters earlier in life among rodents [9], geographical range overlap and more litters per year among bats [10], and larger body mass, larger geographical range and phylogenetic diversification among carnivores [11].

Characterizing epidemiologic features of viral transmission at the animal–human interface has also revealed a number of high-risk human activities that have enabled virus spillover in the past, particularly in situations that facilitate close contact among diverse wildlife species, domesticated animals and people [4]. Moving from individual circumstances to larger scale drivers requires a historical account of how humans have altered the nature of their contact with animals with implications for zoonotic spillover risk. Domestication of animals, human encroachment into habitats high in wildlife biodiversity and hunting of wild animals have been proposed as key anthropogenic activities driving infectious disease emergence at the global scale [12,13]. Many of these same anthropogenic activities have been implicated as the drivers of wildlife population declines and extinction risk. The International Union for Conservation of Nature (IUCN) Red List of Threatened Species [14] is the authority on global population trends for species, as well as criteria for a species to be listed as threatened with extinction. For the many threatened mammal species, these IUCN metrics provide valuable context for large-scale anthropogenic activities implicated in species declines (e.g. decline in habitat quality for a species), and specific animal–human contact (e.g. exploitation of a species). Here we combine data on all zoonotic viruses detected in terrestrial mammalian species with IUCN metrics on trends in species abundance and threats identified in species declines in order to relate broad-scale patterns in species abundance to spillover risk. By systematically evaluating published data on wild and domesticated mammalian species that have viruses in common with humans, we show that species abundance and specific extinction threats are related to the number of viruses shared with humans across mammalian species, with important implications for understanding virus spillover risk.

2. Material and methods

(a) Zoonotic virus and host datasets

Data were collected from the scientific literature on zoonotic viruses and their terrestrial mammalian hosts published through December 2013. Among 142 zoonotic viruses examined, 139 viruses had at least one mammalian host reported at the species level based on polymerase chain reaction (PCR), virus isolation or serology (electronic supplementary material, Data File S1.) We assumed that detection of a zoonotic virus by PCR or serology indicates the potential for that species to serve as a source of virus spillover to humans, by direct or indirect transmission, in the past or at some point in the future. The number of viruses detected in each mammalian species was summed to estimate zoonotic virus richness for each species. Additional details regarding literature search protocols and data inclusion criteria are provided in the electronic supplementary material.

Data on species abundance, species conservation status and criteria for species listing were obtained from The IUCN 2014 Red List of Threatened Species open source database [14]. The IUCN Red List is the official classifier of species at risk of extinction. This resource includes a list of all mammalian species, Red List categories based on extinction risk, most recently documented population trend (decreasing, stable or increasing), and criteria for listing in IUCN threatened categories, as assessed from 2004 to 2013. There are five categories of Red List status based on extinction risk. For this analysis, two categories of extinction risk, least concern (LC) and near threatened (NT), were expanded into six categories based on IUCN classifications for increasing, decreasing and stable population trend (table 1). Decreasing population trend correlated almost perfectly with population reduction (criterion A) for threatened species, so threatened species were not further categorized according to population trend. Estimates of global abundance were obtained from open sources for humans [15] and domesticated species [16]. Domesticated species were categorized as LC, population increasing.

Criteria used to list species as Threatened by the IUCN Red List [14] provided information on threats faced by wild animal species and reasons for species declines. Several criteria evaluated for wild mammals reflect the potential for human-related impacts, including criterion that indicate likelihood of contact with humans. Criteria and sub-criteria categories that were evaluated statistically for their relationship with zoonotic virus richness observed in each

Table 2. Multivariable zero-inflated Poisson regression model predicting the number of zoonotic viruses in mammalian species. (The final zero-inflated Poisson regression model[a] evaluating variation in zoonotic virus richness among extant terrestrial mammalian species is shown with model parameters indicating relative importance (IRR) and significance (with 95% confidence interval) for all variables. Variables significantly associated with the number of zoonotic viruses in a host species included conservation status (as described by the IUCN Red List), criteria for listing of species in a threatened category, taxonomic order, domestication status and (log) number of publications per species in PubMed.)

variables	IRR[b]	95% confidence interval	*p*-value
number of PubMed publications by species (log)	1.281	(1.26, 1.30)	<0.001
conservation status[c]			
least concern increasing	1.528	(1.19, 1.95)	0.001
least concern decreasing	0.750	(0.60, 0.94)	0.011
near threatened decreasing	0.347	(0.23, 0.52)	<0.001
vulnerable threatened status	0.169	(0.09, 0.30)	<0.001
endangered threatened status	0.138	(0.07, 0.25)	<0.001
critically endangered threatened status	0.076	(0.03, 0.16)	<0.001
IUCN criteria for Threatened status[d]			
population size reduction by direct observation (A1, A2, A4(a))	2.601	(1.62, 4.21)	<0.001
decline in area of occupancy or habitat quality (A1–A4(c))	1.840	(1.02, 3.31)	0.042
population size reduction based on levels of exploitation (A1–A4(d))	2.28	(1.36, 3.83)	0.002
small extent of occurrence (B1)	0.192	(0.07, 0.54)	0.002
taxonomic order[e]			
Primates	1.363	(1.13, 1.64)	0.001
Chiroptera	2.112	(1.80, 2.47)	<0.001
Diprotodontia	0.274	(0.12, 0.61)	0.001
Eulipotyphla	0.192	(0.10, 0.36)	<0.001
domesticated species	8.051	(5.89, 11.01)	<0.001

[a]Results shown are from the count model (Poisson with log link). The zero-inflation model (binomial with logit link) incorporates the data deficient/unknown population trend variable result as an odds ratio (OR) predicting excess zeros (OR 4.70, 95% CI 3.60–6.13, $p < 0.001$). This zero-inflated Poisson model showed good overall fit (McFadden's $R^2 = 0.247$).
[b]The incident rate ratio (IRR) reflects the relative influence on the expected number of zoonotic viruses in a given species for a given category compared to the reference category specified. This model incorporates a logit model to predict non-detections in host species designated with 'data deficient/unknown population trend'.
[c]Compared to least concern, stable.
[d]Compared to all other criteria for listing as threatened, based on IUCN Red List criteria used to evaluate whether species belong in a threatened category; for threatened species only [14].
[e]Compared to all other orders.

mammalian species are shown in figure 2. Additional details on the criteria and sub-criteria categories assessed are described in the electronic supplementary material.

Analyses were reliant on investigator-driven reports of viruses in animals, which could bias the estimates of zoonotic virus richness in each species, especially if reporting effort was systematically related to risk factors of interest in this study. We incorporated two independent parameters to adjust for potential reporting bias. First, we quantified research publications available in PubMed for each mammalian species in our dataset, and log number of PubMed publications was included in multivariable modelling. Second, we created a data deficient/unknown trend category for each mammalian species in our dataset using IUCN classifications. When there is inadequate information available to make a population assessment, the IUCN classifies some terrestrial mammalian species as data deficient (DD, $n = 790$). In addition, population trend was unknown for many species, including some NT ($n = 57$) and LC species ($n = 1371$). Species lacking enough data to be categorized according to listing criteria, as well as NT and LC species lacking population trend data, were combined into a data deficient/unknown trend category for analyses (table 1). Our assumption for analyses is that species with less population information were potentially less investigated with respect to zoonotic diseases. Combined measures of threatened status, population trend and data deficiency were summarized as 'conservation status' (table 1).

(b) Statistical analysis

Correlation between zoonotic virus richness and (i) species richness within taxonomic orders and (ii) abundance estimates for humans and domesticated species were evaluated using Spearmans' ρ statistic for non-parametric variables with a two-tailed test of significance. Multivariable zero-inflated Poisson (ZIP) regression modelling was used to evaluate all putative risk factors for their relationship with zoonotic virus richness (sum of zoonotic viruses) in each mammalian species. Model building was initiated with the log number of PubMed publications, and then variables were entered into the model using forward stepwise entry with all categories of a variable being entered at one time, starting with species status categories, then criteria for listing, then domestication status. Incidence rate ratios (IRRs) and their 95% confidence intervals (CIs) are shown for the final ZIP model (table 2). Stepwise model building procedures are described in more detail in the electronic supplementary material. Parameter importance in improving model fit was assessed by the removal

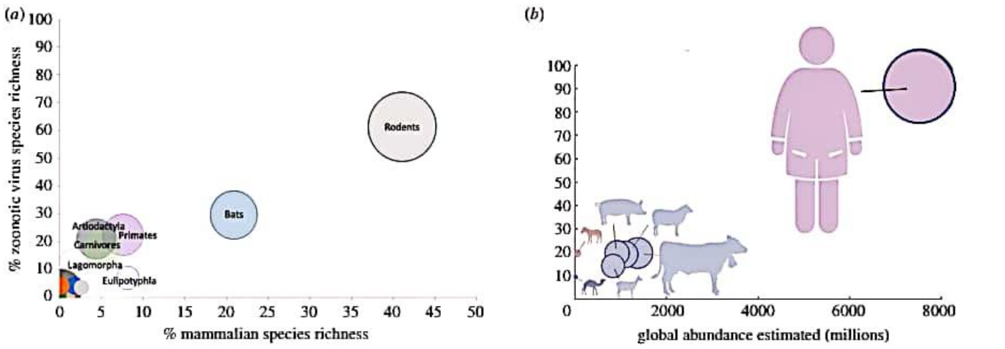


Figure 1. Richness of zoonotic viruses found in mammalian hosts, by taxonomic order for wildlife and by species for domesticated animals and humans. (*a*) Zoonotic virus richness corresponding to species richness among wild mammalian orders. Area of the circles represents the proportion of zoonotic viruses found in species in each order out of the total number of zoonotic viruses among all mammalian species. Orders with less than 5% of zoonotic viruses and less than 2% of mammalian species include Didelphimorphia, Pilosa, Proboscidea, Diprotodontia, Perissodactyla, Cingulata and Dasyuromorphia are not labelled. (*b*) Zoonotic virus richness corresponding to estimated global abundance (in millions) for humans [15] and domesticated species [16]. Species are coloured according to the order in which they belong in (*a*). Area of the circles reflects the estimated population size for that species relative to the other species shown. (Online version in colour.)

of parameter groups one at a time, using ΔAkaike information criteria (AIC) (AIC_{full}–AIC_{fitted}) to compare to the best-fit full model (electronic supplementary material, table S1). We also show the alternate best-fit model, a zero-inflated negative binomial model (electronic supplementary material, table S2), as well as the final ZIP model without the term log number of PubMed publications (electronic supplementary material, table S3) to show model sensitivity to reporting bias.

Statistical analyses were conducted using Stata version 11 SE (StataCorp, College Station, Texas, USA) and the pscl package in R [17,18]. A bipartite (two-mode) affiliation network was generated for virus–host matrix data, stratified by species order. Network data visualization were conducted using the force-directed algorithm ForceAtlas2 [19] in the software platform Gephi version 0.9 [20]. All data used to evaluate the relationship between species status, criteria for listing, species order, domestication status, the number of PubMed publications and zoonotic virus richness recognized to the date of the study in a mammalian species are presented in the electronic supplementary material, Data File S2.

3. Results and discussion

Global-scale analysis across the breadth of all zoonotic viruses reveals structured variation among mammalian species that have been implicated as a potential source of virus spillover to humans, with predictable patterns in zoonotic virus richness related to species domestication and recent trends in wildlife populations. Among 5335 wild terrestrial mammal species, we found that only 11.4% of mammalian species ($n = 609$) have been identified with one or more of the zoonotic viruses investigated here and, of these, most species (58.1%, $n = 354$) have been reported with only one zoonotic virus each. In line with recent studies [5,21], we found that the highest proportion of zoonotic viruses were reported among species in the orders Rodentia (61%), Chiroptera (30%), Primates (23%), Artiodactyla (21%), Carnivora (18%) and fewer viruses were detected in other mammalian orders (figure 1). Zoonotic virus species richness was highly correlated with mammalian species richness when mammalian host species were grouped by taxonomic order ($\rho = 0.791$, $p < 0.001$), indicating that mammalian orders with more species are the source of more zoonotic viruses (figure 1*a*), as has been detected in a similar dataset of zoonotic diseases [21]. We found that three mammalian orders (rodents, bats and primates) have together been implicated as hosts for the majority (75.8%) of zoonotic viruses described to date, and these orders represent 72.7% of all terrestrial mammal species. As a group, domesticated mammals host 50% of the zoonotic virus richness but represent only 12 species. Zoonotic virus richness in domesticated mammalian species was highly correlated with global abundance estimates for humans and domesticated species ($\rho = 0.875$, $p = 0.004$, figure 1*b*), even when data on humans were dropped from analysis (without humans; $\rho = 0.808$, $p = 0.028$).

The majority (88.6%) of terrestrial mammalian species have not yet been reported with a zoonotic virus, so the ZIP model was fit with 'data deficient' as the variable predicting excess zeros in the data. Holding all other factors in the model constant, an increase in the number of PubMed publications for a species was associated with an increased number of zoonotic viruses reported in that species (table 2). Adjusting for reporting bias prior to the interpretation of other putative factors was important, given publication of zoonotic hosts in the literature was the basis for inclusion in this study, and the inclusion of number of PubMed publications improved model fit as evidenced by change in AIC (electronic supplementary material, table S1). The final ZIP model indicates that conservation status, several criteria for species reductions, taxonomic order and domesticated species status were also significantly related to the number of zoonotic viruses detected in each mammalian species (table 2). Relationships between conservation status, criteria, order, domestication and species richness in zoonotic viruses were robust to alternate model formulations, including zero-inflated negative binomial regression (electronic supplementary material, table S2) and ZIP regression without the term needed to adjust for reporting bias (electronic supplementary material, table S3).

(a) Zoonotic virus richness scales with wild mammalian abundance

We detected a direct positive relationship between conservation status and the number of viruses shared between that species and humans after adjusting for domestication status, taxonomy, criteria for listing threatened species, and the number of PubMed publications at the species level (table 2). Less common wildlife species, categorized with increasingly threatened status by the IUCN Red List, were implicated with significantly fewer viruses shared with people, compared to widespread and abundant wild mammalian species. Terrestrial wild animal species of least concern with increasing population trends ($n = 58$) were reported with significantly more zoonotic viruses, while species with decreasing population trends ($n = 391$) had significantly fewer zoonotic viruses, compared to species with stable population trends ($n = 1281$). After adjusting for all factors, we detected a dose-response type relationship between increasingly threatened conservation status and a corresponding decrease in the number of viruses mammals share with humans. The gradual decrease in incidence rate ratios as species abundance declines from least concern conservation status with increasing population trend to critically endangered provides evidence for this trend (table 2). With the exception of species categorized as threatened owing to over-exploitation and habitat loss, this trend can be summarized as follows; species of least concern with increasing abundance were estimated with 1.5 times the number of zoonotic viruses, while species of least concern with decreasing abundance had three-fourths the number of viruses, species not threatened, but decreasing in abundance had one-third the number of viruses, vulnerable species had less than one-sixth the number of viruses, endangered species had one-seventh the number of viruses, and critically endangered had one-thirteenth the number of viruses, compared to species of least concern that were stable in abundance. In an additional analysis of a subset of species that were not found to be data deficient, we found conservation status had a positive linear relationship with the number of zoonotic viruses reported in a species (data shown in the electronic supplementary material).

We found that threatened species listed because of their small extent of occurrence (IUCN Red List category B1, $n = 499$ species) harboured approximately one-fifth as many zoonotic viruses compared to species listed for other reasons when all predictors, including detection bias, were included in the model (table 2). Other IUCN Red List criteria and sub-criteria indicative of small extent of habitat (figure 2) were also correlated with fewer virus detections in a species. In fact, threatened species listed because of very small area of occupancy (IUCN Red List criteria B2), and very small or restricted populations (IUCN Red List criteria D2) have yet to be reported with any zoonotic viruses (figure 2). Previous analyses of parasite richness in primates have found that total parasite richness was lower for species with threatened status, suggesting that small populations with limited geographical range harbour fewer parasites overall [22,23].

Wild mammals with threatened conservation status (i.e. IUCN's Vulnerable, Endangered or Critically Endangered status) are increasingly rare, and the probability of a human encounter is thus presumed to be less likely, unless a species has adapted to human-dominated habitats or is otherwise in frequent contact with humans. Endangered and critically endangered species include many of the most charismatic and intensively managed species in the world, and thus we expected opportunities for virus spillover from species to be more frequent from these species. To further evaluate disparities in zoonotic virus richness among threatened species, we assessed the Red List's listing criteria and sub-criteria in a multivariable modelling approach and found that threatened species for which a population reduction was directly observed (IUCN Red List criteria A1(a), A2 (a) or A4 (a), $n = 53$ species) were predicted to host over 2 times as many zoonotic viruses, compared to species listed as threatened by other means when all other variables were accounted for in the model (table 2). Wildlife populations with declines that have been directly observed were probably more closely monitored to be able to detect changes in population abundance, and often, long-term monitoring programmes accompany species management plans, thereby increasing the likelihood of disease detection and reporting. Also, intensive and often hands-on wildlife management can increase opportunities for pathogen transmission from animals to humans, supporting a biological basis for increased spillover risk beyond increased detection. Direct and indirect contact with wildlife in management and ecotourism settings is a recognized risk for zoonotic spillover, along with increased occupational risk among veterinarians and researchers attending to wildlife [4].

(b) Convergence in drivers for mammalian species declines and zoonotic virus richness

Among all criteria used to categorize species as threatened with extinction, we identified three additional criteria significantly related to the number of viruses a mammal shares with humans (table 2). After adjusting for other significant effects in the multivariable model, we find that threatened species with a population size reduction owing to exploitation (IUCN Red List category A1–A4(d), $n = 256$ species) have over twice as many zoonotic viruses as compared to threatened species listed for other reasons (table 2). Exploitation of wildlife through hunting and the wild animal trade have been hypothesized as increasing opportunities for pathogen spillover because of the close contact between wildlife and humans involved in these activities [4,12,24,25].

Threatened species with population reductions owing to declines in occupancy, extent of occurrence and/or habitat quality (A1–A4(c), $n = 353$ species) were also predicted to host nearly twice as many zoonotic viruses compared to threatened species declining for other reasons, if all other factors were held constant (table 2). Anthropogenic activities that have altered the landscape, such as forest fragmentation, development and conversion to cropland, have caused declines in wildlife habitat quality, and, as with exploitation, are likely to also increase the probability of animal–human interactions during and subsequent to land conversion activities [26,27]. Human encroachment into biodiverse areas increases the risk of spillover of novel infectious diseases by enabling new contacts between humans and wildlife [28]. Slightly more than half of all threatened species (54.8%) were listed by IUCN because of the impacts of exploitation or habitat loss on species abundance indicating that this is a major impetus for species reductions. Our analysis incorporating data on species declines globally provides broad-scale support for convergent processes whereby exploitation of wildlife and habitat loss have caused wildlife population declines, as well as facilitated the transmission of animal viruses to humans that most likely occurred prior to and during large-scale losses in abundance.

(c) Domesticated species share the highest number of viruses with humans

Domestication of livestock has played a well-recognized role in transmission of zoonotic viruses to people, as would be

royalsocietypublishing.org/journal/rspb Proc. R. Soc. B 287: 20192736

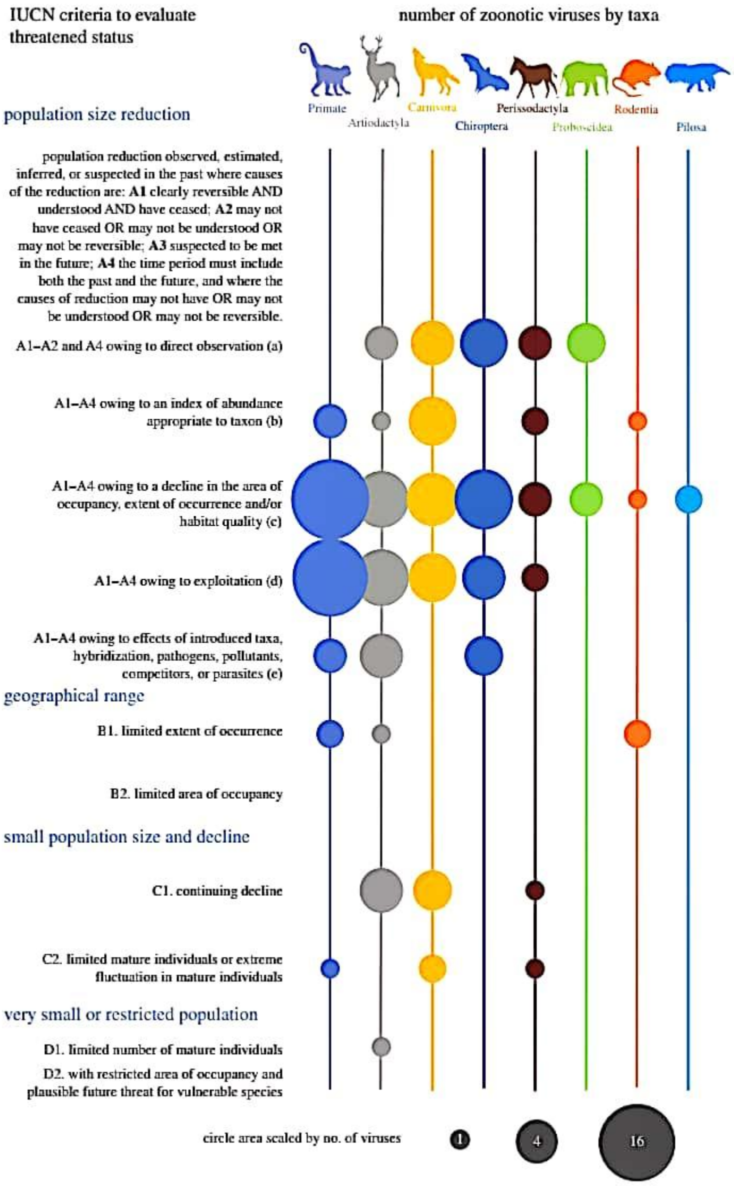


Figure 2. Number of mammalian viruses shared with humans for each taxonomic order by IUCN threatened species criteria. The number of zoonotic viruses reported in threatened wildlife species, shown by relative circle area for each taxonomic order according to the scale shown. Scale of circle areas range from one virus (as exemplified by criteria D1 for Artiodactyla) to 16 viruses (as exemplified by criteria A1–A4(c) for primates). Numbers of viruses are not adjusted for factors found to be related to species virus counts in multivariable regression modelling. Species in each order were categorized by the IUCN Red List criteria as adapted for this study. Refer to the IUCN Red List categories and criteria for a detailed explanation of the criteria used by the IUCN to evaluate species trends and place species into threatened categories [14]. (Online version in colour.)

expected of animal species that are unprecedented in their distribution, often reared in dense populations, and have been in close contact with people for centuries [13]. We find that domesticated species status had the largest influence on the number of mammalian viruses shared with humans with eight times more zoonotic viruses predicted in a given domesticated mammal species compared to wild mammalian species (table 2). Domesticated species harboured an average of 19.3 zoonotic viruses (min 5, max 31) compared to wild species with a mean of 0.23 viruses (min 0, max 16). The top 10 mammalian species with the highest number of viruses shared with humans included eight domesticated species: pigs ($n = 31$ zoonotic viruses), cattle ($n = 31$ zoonotic viruses), horses ($n = 31$ zoonotic viruses), sheep ($n = 30$ zoonotic

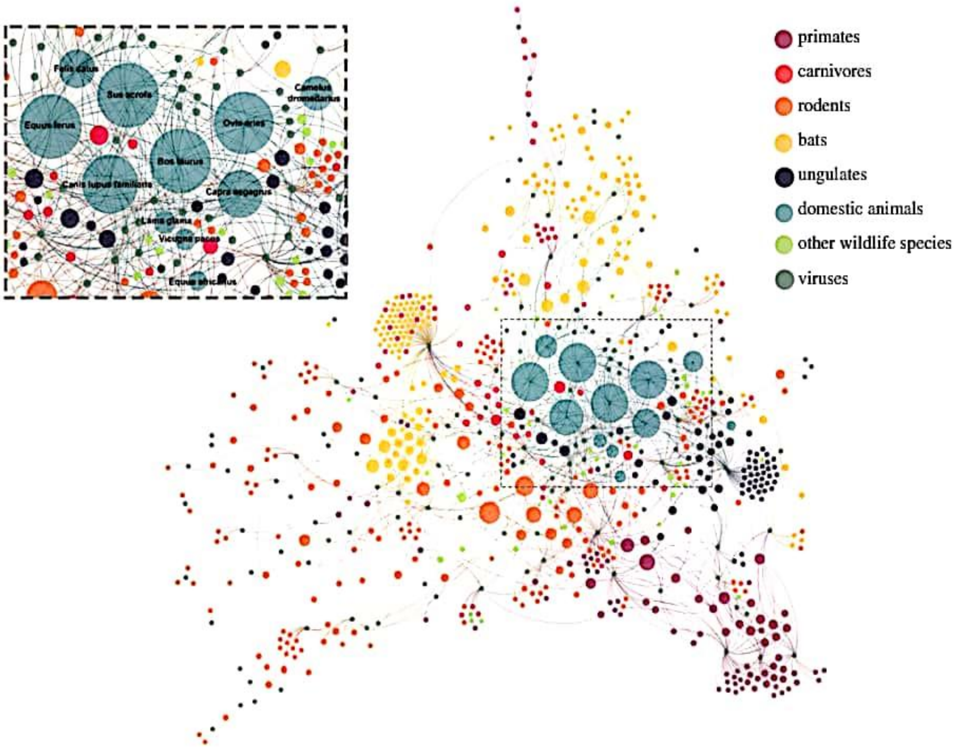


Figure 3. Bipartite network showing wild and domesticated mammalian species and their zoonotic virus associations. Host species harbouring the same zoonotic virus are linked by shared zoonotic viruses (grey nodes). Mammalian species nodes are coloured by domestication status and taxonomic order for non-domesticated terrestrial wildlife as shown. Species node size is relative to the zoonotic virus richness calculated in that species. Humans, who are host to all viruses, are not shown. (Online version in colour.)

viruses), dogs ($n = 27$ zoonotic viruses), goats ($n = 22$ zoonotic viruses), cats ($n = 16$ zoonotic viruses) and camels ($n = 15$ zoonotic viruses). Aside from humans, accurate detection and reporting of zoonotic viruses would be most probable in domesticated species, given the economic and public health demand for these data. More accurate detection in domesticated species is supported by the minimal change in estimated number of viruses in regression models with the number of publications (table 2) and without the number of publications as an adjustment for reporting bias (electronic supplementary material, table S3). The only wild animals among the top 10 species with detected zoonotic viruses were the house mouse (*Mus musculus*) and the black rat (*Rattus rattus*), with 16 and 14 zoonotic viruses, respectively. Both of these species in the Rodentia order are considered invasive in most regions of the world, commonly inhabit domestic and peri-domestic structures, and have dubious non-domestication status given their use in laboratory studies and as pets worldwide. Sympatry, or spatial overlap of hosts, was highly correlated with cross-species transmission among rodents, and network analyses illustrate that the global distribution of the house mouse has facilitated the transmission of viruses to sympatric species around the world [29].

Additional support for species domestication as a key feature of increased propensity for sharing viruses with humans is provided by the bipartite network of zoonotic viruses sharing among all mammalian hosts (figure 3). Notably, domestic animals are among the most central species in the viral sharing network. Viruses in domesticated species were not only commonly shared with other domesticated species but also with wild animal species within respective Cetartiodactyla and Carnivora orders (figure 3). While directionality in historical transmission of viruses between wild mammals and their domesticated kin can only be inferred, we postulate that wild mammals were the original host for the majority of viruses, sharing viruses with domesticated species over centuries of coevolution and domestication. Artiodactyl wild ungulates have been a dominant source of food throughout history and share habitat with domesticated kin. Close phylogenetic relatedness between globally distributed domesticated species and their wild perissodactyl, artiodactyl and carnivore brethren has probably intensified opportunities for cross-species pathogen transmission [30]. Primate, rodent and bat species appear to harbour zoonotic viruses that are not well connected to domesticated species and other wild animal species (figure 3), supporting the premise that these species share zoonotic viruses directly with humans, without domesticated amplifying hosts facilitating viral sharing among species in other orders.

(d) Primates and bats share more viruses with humans

We found that species in the primate and bat orders were significantly more likely to harbour zoonotic viruses compared to all other orders, after adjusting for domestication, trends in species abundance, criteria for listing and the number of PubMed publications at the species level (table 2). By contrast, Diprotodontia (marsupials) and Eulipotyphla (shrews, moles, hedgehogs) had fewer zoonotic viruses detected by the time of this study than species in other orders. A recent study evaluating the relationship between phylogeny and the proportion of viruses likely to be zoonotic for a given species also found that bats hosted significantly more zoonotic viruses than other orders and that primates drove the phylogenetic effect as a determinant of zoonotic spillover [5]. The close phylogenetic relationship of humans with non-human primates is recognized as a causal factor underlying spillover, reverse zoonoses and the coevolution of occasionally shared viruses [31]. Bats have also been repeatedly implicated as the source of recent emerging infectious disease events involving high consequence pathogens, including severe acute respiratory syndrome (SARS) [32], Nipah virus encephalitis [33], and hemorrhagic fevers caused by filoviruses [34,35], and have been noted previously to host more zoonotic viruses per species than rodents [10]. Viral sharing has been shown to be more common among bat species than among rodent species and several bat traits have been associated with a higher propensity for cross-species transmission, including gregariousness (roosting in high densities) and migration [29]. With nearly a quarter of bat species lacking sufficient data for categorization of their IUCN Red List status, bats are probably still under-represented in field investigations and warrant future dedicated focus for emerging infectious disease research.

5. Conclusion and future directions

Infectious diseases from wildlife have emerged at an increased pace within the last century [36] and are likely to continue to emerge, given expected increases in population growth and landscape change. Curbing disease emergence will prove challenging until we have a more thorough appreciation of the epidemiologic circumstances that facilitate pathogen spillover, particularly from wild animals, which are the source of the majority of recently emerging infectious diseases [2] and continue to constitute a substantial gap in disease detection efforts worldwide. Here, we find broad evidence supporting large-scale mechanisms underlying patterns of zoonotic virus richness across species, by which trends in mammalian abundance and drivers of declines among threatened species reflect animal–human interactions that facilitate virus transmission to people.

By identifying a positive relationship between global trends in mammalian abundance and an increased number of mammalian viruses that have been shared with humans, our findings suggest that mammal species with larger global populations pose greater risk for virus spillover. Our data also provide new evidence that threatened wildlife species with limited extent of occurrence and small population sizes have shared relatively fewer viruses with humans, supporting the concept that virus spillover risk at this large scale is underpinned by the probability of animal–human interactions. Reservoir populations have a critical population or community size required for infectious disease transmission [37], and generally larger populations are more likely to propagate cycles of infection. Population range size similarly reflects opportunities for animal contact, and species with larger ranges should have increased potential to overlap in range, and possibly share habitat with other species, enabling cross-species transmission and increasing the risk of spillover to humans [29]. However, determinants identified as predictors of zoonotic virus richness at this scale might not relate to zoonotic virus diversity in species at the local scale. Larger population size together with higher population density have been shown to positively correlate with higher viral richness among primate species [22], consistent with disease transmission mechanisms that are dependent on population densities and distributions.

Given we detected a significant increase in zoonotic virus richness among more globally abundant species, additional mechanisms underlying trends in wildlife populations warrant investigation. Species that have increased in abundance and even expanded their range despite large-scale anthropogenically driven landscape change and urbanization [38] are more likely to be generalist species that have adapted to human-dominated landscapes. Approximately one quarter of mammalian species had stable or increasing trends in abundance at the time of analysis, half of which were rodents [14]. While urbanization and landscape change towards crop production could decrease biodiversity overall, these activities can increase the abundance of select species [39]. Many species listed as least concern with increasing abundance by the IUCN Red List are adaptable wild mammalian species that have benefitted from a close relationship with humans. These species could have habitat and dietary niches that overlap with humans in dwellings or in agricultural practices, further enabling direct and indirect contact with similarly adapted sympatric species, domesticated species and humans. In particular, dwellings and agricultural settings are among the most high risk of interfaces for zoonotic viral transmission, particularly from rodents [4]. Pathogen transmission among animals thriving in human-dominated landscapes can also benefit from higher community size and density-dependent viral transmission, especially when resources that sustain mammal populations are aggregated [40], further increasing the probability of human contact with infectious reservoirs in these landscapes. With ongoing landscape transformation towards human-dominated landscapes and approximately half of the world's human population living in urbanized communities [41], species that are adaptable to human modified habitat are likely to continue to be an important source of zoonotic pathogen transmission [40].

Over 20% of mammalian species were threatened with extinction at the time of this analysis, and exploitation and declines in habitat were implicated in the listing status for over half of these threatened species [14]. The IUCN Red List of Threatened Species criteria for categorizing species status [14] was used here to represent large-scale animal–human interactions involved in spillover that could not be measured directly at the species level across all mammalian species. Refined measures of wild animal interactions with people that could constitute effective contact for disease transmission are needed at the local level that can also be scaled up to evaluate broader patterns in spillover risk. We included both serological and molecular data in our analyses, as well as an adjustment for reporting bias, because we were especially concerned about missing host–virus associations. Disease surveillance has been very limited for many wildlife species to date, and wildlife reservoir status can be difficult to ascertain, particularly for viruses with a very short duration of shedding, after which antibodies might only be detectable by serology.

Our model findings were robust to detection bias overall, with the same significant factors explaining variation in species propensity to host zoonotic viruses retaining a similar relative effect and significance even when the number of PubMed publications was not accounted for in the model (electronic supplementary material, table S3). Nonetheless, large-scale surveillance efforts are necessary to more specifically identify epidemiologically relevant animal reservoirs for zoonotic viruses, as well as the periods of heightened shedding that might be related to specific host traits and environmental factors measured at the species level. Wild animal hosts for zoonotic viruses have been vastly under-recognized because the majority of species have not been sampled at the level needed to detect zoonotic viruses, and many geographical regions lack adequate data for modelling [5].

We find evidence to support the premise that abundant mammal species have shared more viruses with humans than less abundant species and that the exploitation of wildlife could have potentiated virus spillover risk. Global patterns in spillover risk reflect close contact interactions between wildlife and humans that occur in a myriad of circumstances around the world. While we shed light on the patterns of zoonotic viruses that have been reported up through the time of this study, we suspect that pathogen spillover often goes unnoticed, with only a proportion of spillover events expanding into outbreaks in people that are subsequently detectable. The evidence of serologic exposure to zoonotic pathogens with high mortality in humans, such as filoviruses, in areas not previously recognized with outbreaks, supports the premise that zoonotic pathogen exposure is more common than recognized [42]. Surveillance for acute febrile illness among people engaged in high-risk activities involving animals, especially wildlife, is a priority to enable more rapid detection of emerging and re-emerging infectious diseases. Surveillance activities that include animals and humans in close contact situations will advance outbreak preparedness in between outbreaks and assist in prioritizing in-depth, longitudinal field studies needed to understand epidemiological patterns in virus transmission and optimize disease prevention actions. Informed mitigation efforts aimed at ensuring biosafety in livestock production, minimizing interactions between wildlife and domesticated animals and limiting close contact with wildlife are especially needed given global trends in urbanization and food production. One Health surveillance approaches are needed that integrate animal and human health in monitoring for emerging infectious diseases and consider environmental change that is likely to intensify close proximity animal–human interactions in the near future.

Data accessibility. The datasets supporting this article have been uploaded as part of the electronic supplementary material.

Authors' contributions. C.K.J. designed the study, analysed data and wrote the manuscript; P.L.H. designed the study, collected data, analysed data and contributed to the manuscript; P.P. analysed data and contributed to the manuscript; J.R. analysed data and contributed to the manuscript; T.S.E. collected data and contributed to the manuscript; C.C.W.Y. analysed data and contributed to the manuscript; M.D. collected data and contributed to the manuscript.

Competing interests. The authors have no competing interests.

Funding. This work was supported by the United States Agency for International Development (USAID) Emerging Pandemic Threat PREDICT program (Cooperative Agreement no. GHN-AOO-09-00010-00). T.S.E. was supported by NIH/Fogarty K01 International Research Scientist Development Award (1K01TW010279-01). The contents of this paper are the responsibility of the authors and do not necessarily reflect the views of USAID or the United States Government.

References

1. Woolhouse ME, Gowtage-Sequeria S. 2005 Host range and emerging and reemerging pathogens. *Emerg. Infect. Dis.* **11**, 1842–1847. (doi:10.3201/eid1112.050997)
2. Taylor LH, Latham SM, Woolhouse ME. 2001 Risk factors for human disease emergence. *Phil. Trans. R Soc. Lond. B* **356**, 983–989. (doi:10.1098/rstb.2001.0888)
3. Heymann DL *et al.* 2015 Global health security: the wider lessons from the west African Ebola virus disease epidemic. *Lancet* **385**, 1884–1901. (doi:10.1016/S0140-6736(15)60858-3)
4. Kreuder Johnson C *et al.* 2015 Spillover and pandemic properties of zoonotic viruses with high host plasticity. *Sci. Rep.* **5**, 14830. (doi:10.1038/srep14830)
5. Olival KJ, Hosseini PR, Zambrana-Torrelio C, Ross N, Bogich TL, Daszak P. 2017 Host and viral traits predict zoonotic spillover from mammals. *Nature* **546**, 646–650. (doi:10.1038/nature22975)
6. Woolhouse M, Gaunt E. 2007 Ecological origins of novel human pathogens. *Crit. Rev. Microbiol.* **33**, 231–242. (doi:10.1080/10408410701647560)
7. Woolhouse M, Scott F, Hudson Z, Howey R, Chase-Topping M. 2012 Human viruses: discovery and emergence. *Phil. Trans. R Soc. B* **367**, 2864–2871. (doi:10.1098/rstb.2011.0354)
8. Stephens PR *et al.* 2016 The macroecology of infectious diseases: a new perspective on global-scale drivers of pathogen distributions and impacts. *Ecol. Lett.* **19**, 1159–1171. (doi:10.1111/ele.12644)
9. Han BA, Schmidt JP, Bowden SE, Drake JM. 2015 Rodent reservoirs of future zoonotic diseases. *Proc Natl Acad. Sci. USA* **112**, 7039–7044. (doi:10.1073/pnas.1501598112)
10. Luis AD *et al.* 2013 A comparison of bats and rodents as reservoirs of zoonotic viruses: are bats special? *Proc. R. Soc. B* **280**, 20122753. (doi:10.1098/rspb.2012.2753)
11. Huang S, Drake JM, Gittleman JL, Altizer S. 2015 Parasite diversity declines with host evolutionary distinctiveness: a global analysis of carnivores. *Evolution* **69**, 621–630. (doi:10.1111/evo.12611)
12. Wolfe ND, Daszak P, Kilpatrick AM, Burke DS. 2005 Bushmeat, hunting, deforestation, and prediction of zoonotic disease emergence. *Emerg. Infect. Dis.* **11**, 1822–1827. (doi:10.3201/eid1112.040789)
13. Wolfe ND, Dunavan CP, Diamond J. 2007 Origins of major human infectious diseases. *Nature* **447**, 279–283. (doi:10.1038/nature05775)
14. International Union for the Conservation of Nature (IUCN). The IUCN Red List of threatened species. Version 2017-1. See http://www.iucnredlist.org.
15. United Nations. 2017 World population prospects: the 2017 revision, key findings and advance tables. See https://www.un.org/development/desa/publications/world-population-prospects-the-2017-revision.html.
16. Food and Agriculture Organization of the United Nations. 2017. FAOSTAT. See www.fao.org/faostat/.
17. R Core Team. 2017 *R: a language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing.
18. Zeileis A, Kleiber C, Jackman S. 2008 Regression models for count data in R. *J. Stat. Softw.* **27**, 1–25. (doi:10.18637/jss.v027.i08)
19. Jacomy M, Venturini T, Heymann S, Bastian M. 2014 ForceAtlas2, a continuous graph layout algorithm for handy network visualization designed for the Gephi software. *PLoS ONE* **9**, e98679. (doi:10.1371/journal.pone.0098679)
20. Bastian M, Heymann S, Jacomy M. 2009 Gephi: an open source software for exploring and manipulating networks. *Icwsm* **8**, 361–362.

21. Han BA, Kramer AM, Drake JM. 2016 Global patterns of zoonotic disease in mammals. *Trends Parasitol.* **32**, 565–577. (doi:10.1016/j.pt.2016.04.007)
22. Nunn CL, Altizer S, Jones KE, Sechrest W. 2003 Comparative tests of parasite species richness in primates. *Am. Nat.* **162**, 597–614. (doi:10.1086/378721)
23. Altizer S, Nunn CL, Lindenfors P. 2007 Do threatened hosts have fewer parasites? A comparative study in primates. *J. Anim. Ecol.* **76**, 304–314. (doi:10.1111/j.1365-2656.2007.01214.x)
24. Karesh WB, Cook RA, Bennett EL, Newcomb J. 2005 Wildlife trade and global disease emergence. *Emerg. Infect. Dis.* **11**, 1000–1002. (doi:10.3201/eid1107.050194)
25. Karesh WB, Noble E. 2009 The bushmeat trade: increased opportunities for transmission of zoonotic disease. *Mt Sinai J. Med.* **76**, 429–434. (doi:10.1002/msj.20139)
26. Hahn MB, Gurley ES, Epstein JH, Islam MS, Patz JA, Daszak P, Luby SP. 2014 The role of landscape composition and configuration on *Pteropus giganteus* roosting ecology and Nipah virus spillover risk in Bangladesh. *Am. J. Trop. Med. Hyg.* **90**, 247–255. (doi:10.4269/ajtmh.13-0256)
27. Rulli MC, Santini M, Hayman DTS, D'Odorico P. 2017 The nexus between forest fragmentation in Africa and Ebola virus disease outbreaks. *Sci. Rep.* **7**, 41613. (doi:10.1038/srep41613)
28. Wilkinson DA, Marshall JC, French NP, Hayman DTS. 2018 Habitat fragmentation, biodiversity loss and the risk of novel infectious disease emergence. *J. R. Soc. Interface* **15**, 20180403. (doi:10.1098/rsif.2018.0403)
29. Luis AD, O'Shea TJ, Hayman DTS, Wood JLN, Cunningham AA, Gilbert AT, Mills JN, Webb CT. 2015 Network analysis of host-virus communities in bats and rodents reveals determinants of cross-species transmission. *Ecol. Lett.* **18**, 1153–1162. (doi:10.1111/ele.12491)
30. Pedersen AB, Jones KE, Nunn CL, Altizer S. 2007 Infectious diseases and extinction risk in wild mammals. *Conserv. Biol.* **21**, 1269–1279. (doi:10.1111/j.1523-1739.2007.00776.x)
31. Gomez JM, Nunn CL, Verdu M. 2013 Centrality in primate-parasite networks reveals the potential for the transmission of emerging infectious diseases to humans. *Proc. Natl Acad. Sci. USA* **110**, 7738–7741. (doi:10.1073/pnas.1220716110)
32. Wang LF, Shi Z, Zhang S, Field H, Daszak P, Eaton BT. 2006 Review of bats and SARS. *Emerg. Infect. Dis.* **12**, 1834–1840. (doi:10.3201/eid1212.060401)
33. Yob JM *et al.* 2001 Nipah virus infection in bats (order Chiroptera) in peninsular Malaysia. *Emerg. Infect. Dis.* **7**, 439–441. (doi:10.3201/eid0703.017312)
34. Amman BR *et al.* 2012 Seasonal pulses of Marburg virus circulation in juvenile *Rousettus aegyptiacus* bats coincide with periods of increased risk of human infection. *PLoS Pathog.* **8**, e1002877. (doi:10.1371/journal.ppat.1002877)
35. Schuh AJ, Amman BR, Towner JS. 2017 Filoviruses and bats. *Microbiol Aust.* **38**, 12–16. (doi:10.1071/ma17005)
36. Jones KE, Patel NG, Levy MA, Storeygard A, Balk D, Gittleman JL, Daszak P. 2008 Global trends in emerging infectious diseases. *Nature* **451**, 990–993. (doi:10.1038/nature06536)
37. Lloyd-Smith JO, Cross PC, Briggs CJ, Daugherty M, Getz WM, Latto J, Sanchez MS, Smith AB, Swei A. 2005 Should we expect population thresholds for wildlife disease? *Trends Ecol. Evol.* **20**, 511–519. (doi:10.1016/j.tree.2005.07.004)
38. Pandit R, Scholes R, Montanarella L, Brainich A, Barger N, ten Brink B, Willemen L. 2018 Summary for policymakers of the assessment report on land degradation and restoration of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. See https://ipbes.net/assessment-reports/ldr.
39. Bradley CA, Altizer S. 2007 Urbanization and the ecology of wildlife diseases. *Trends Ecol. Evol.* **22**, 95–102. (doi:10.1016/j.tree.2006.11.001)
40. Becker DJ, Streicker DG, Altizer S. 2015 Linking anthropogenic resources to wildlife-pathogen dynamics: a review and meta-analysis. *Ecol. Lett.* **18**, 483–495. (doi:10.1111/ele.12428)
41. Johnson CN, Balmford A, Brook BW, Buettel JC, Galetti M, Guangchun L, Wilmshurst JM. 2017 Biodiversity losses and conservation responses in the Anthropocene. *Science* **356**, 270–275. (doi:10.1126/science.aam9317)
42. Smiley Evans T *et al.* 2018 Suspected exposure to filoviruses among people contacting wildlife in southwestern Uganda. *J. Infect. Dis.* **79**, 62. (doi:10.1016/j.ijid.2018.11.160)

[ANNEXURE-E]

BEFORE THE MADURAI BENCH OF MADRAS HIGH COURT
(Civil Appellate Jurisdiction)

Thursday, the Twenty Seventh day of February Two Thousand Fourteen

PRESENT

The Hon`ble Mr.Justice R. SUDHAKAR
and
The Hon`ble Ms.Justice V.M.VELUMANI

WP(MD) No.3633 of 2014

M. SARAVANAN ... PETITIONER

Vs

1 THE PRINCIPAL SECRETARY
DEPARTMENT OF FORESTS AND ENVIRONMENT, ST. GEORGE FORT, CHENNAI- 600 009.

2 PRINCIPAL SECRETARY
DEP. OF REVENUE, ST. GEORGE FORT, CHENNAI- 600 009.

3 THE PRINCIPAL CHIEF
CONSERVATOR OF FORESTS, GOVT.,OF TAMIL NADU, PANAGAL BUILDING, SAIDEPET, CHENNAI 600 015.

4 THE DISTRICT COLLECTOR
DINDIGUL DISTRICT, DINDIGUL.

5 THE DISTRICT FOREST OFFICER
KODAIKANAL, DINDIGUL DISTRICT ... RESPONDENT(S)

Petition praying that in the circumstances stated therein and in the affidavit filed therewith the High Court will be pleased to issue a writ of Mandamus directing the respondents to take appropriate measures to remove the wattle, eucalyptus trees grown in the forests of the respondent no.3 department in the Western Ghats in the Tamil Nadu region with in the time period stipulated by this Hon'ble Court.

ORDER : This petition coming on for orders upon perusing the petition and the affidavit filed in support thereof and upon hearing the arguments of M/S T.LAJAPATHI ROY, Advocate for the petitioner and of Mr.B.Pugalendhi Special Government Pleader on behalf of the Respondents the court made the following order:-

This writ petition filed in public interest raises a very important issue with regard to the restoration of forests in the hill station of Kodaikanal, Nilgiris and other hill stations in Tamil Nadu including Western Ghats. The forests in these areas, more particularly, in Kodaikanal has dwindled due to various ecological imbalances. One important factor that has been pointed out in this writ petition is the impact of the commercial plantation of wattle and eucalyptus trees which have destroyed the Shola forests.

2. Materials have been placed in support of the writ petition stating that the Shola forests were in existence in a wide area of Palani hills and Kodaikanal hills. This extent has been greatly reduced due to the

destruction of Shola forests for commercial exploitation. Planting of wattle trees and eucalyptus trees has affected the eco-system in the Shola forest. The grass lands have also been affected. Consequently, the food chain right from the planktons to the panthers and tigers in the Shola forests, is affected. Various mammals and birds species in these areas, depend on the preservation and conservation of the Shola forest.

3. The elevation of these hill areas has given a rise to tropical rain forests , more particularly, in Western Ghats. It is, these tropical rain forests, that provide best of ecology for all living creatures and sustain a good environment for the entire geographical location.

4. In order to ensure that the valuable Shola forests and grass lands are maintained, effective steps have to be taken by the Department of Forests and Environments and the Principal Chief Conservator of Forests, Government of Tamil Nadu, Chennai, to ensure that Shola forests and tropical rain forests are restored to its original state. In this regard, the authority concerned has to take steps to annihilate wattle and eucalyptus trees in the forests of Kodaikanal hills, Palani hills and in the Western Ghats of Tamil Nadu region and save the forests.

5. Taking serious note of the matter, the respondent authorities are directed to formulate a comprehensive scheme, if not already framed, for restoration of Shola forests and tropical rain forests in the Kodaikanal hills, Nilgiris, Palani hills and the Western Ghats. This should be done in a systematic and phased manner.

6. An Action Taken Report in this regard should be filed before this Court along with proper records on or before **07.04.2014**.

7. Since the restoration of Shola forests as well as the tropical rain forests in the Kodaikanal hills, Palani hills, Nilgiris and the Western Ghats of Tamil Nadu is a long drawn process, we are of the view that this petition will have to be listed periodically so as to issue directions from time to time, so that, the above stated object is achieved in public interest.

8. Admit. Notice to the respondents returnable by **07.04.2014.**

9. This writ petition shall be listed on the first working day of every month before this Court to ensure continuous monitoring and for passing appropriate orders as may be necessary.

10. List the matter on **07.04.2014** under the caption "Kodaikanal Shola Forests Restoration".

sd/-
27/02/2014

/ TRUE COPY /

Sub-Assistant Registrar

TO

1 THE PRINCIPAL SECRETARY
DEPARTMENT OF FORESTS AND ENVIRONMENT, ST.
GEORGE FORT, CHENNAI- 600 009.

2 THE PRINCIPAL SECRETARY
DEP. OF REVENUE, ST. GEORGE FORT, CHENNAI- 600 009.

3 THE PRINCIPAL CHIEF
CONSERVATOR OF FORESTS, GOVT.,OF TAMIL NADU,
PANAGAL BUILDING, SAIDEPET, CHENNAI 600 015.

4 THE DISTRICT COLLECTOR, DINDIGUL DISTRICT, DINDIGUL.

5 THE DISTRICT FOREST OFFICER,KODAIKANAL, DINDIGUL DISTRICT

+1. C.C. to M/S T.LAJAPATHI ROY Advocate SR.No.12944.

+1cc to Special Government Pleader in SR.No. 12828.

TS/28.02.2014/2P-8C

ORDER
IN
WP(MD) No.3633 of 2014
Date :27/02/2014

[ANNEXURE-F]

BEFORE THE MADURAI BENCH OF MADRAS HIGH COURT
(Special Original Jurisdiction)

Monday, the Tenth day of August Two Thousand Fifteen

PRESENT

The Hon`ble Mr.Justice R. SUDHAKAR
and
The Hon`ble Ms.Justice V.M.VELUMANI

WP(MD) No.3633 of 2014

M.SARAVANAN ..Petitioner

Vs.

1 THE PRINCIPAL SECRETARY
DEPARTMENT OF FORESTS AND ENVIRONMENT,
ST. GEORGE FORT, CHENNAI- 600 009.

2 PRINCIPAL SECRETARY
DEPARTMENT OF REVENUE,
ST. GEORGE FORT, CHENNAI- 600 009.

3 THE PRINCIPAL CHIEF CONSERVATOR OF FORESTS,
GOVERNMENT OF TAMIL NADU,
PANAGAL BUILDING, SAIDEPET,
CHENNAI 600 015.

4 THE DISTRICT COLLECTOR
DINDIGUL DISTRICT, DINDIGUL.

5 THE DISTRICT FOREST OFFICER
KODAIKANAL, DINDIGUL DISTRICT

6 K.KUMARAN,
(R6 IS IMPLEADED VIDE COURT ORDER
DT.04.08.15 IN MP.2/14) ..RESPONDENTS

Petition praying that in the circumstances stated therein and in the affidavit filed therewith the High Court will be pleased to issue a writ of Mandamus directing the respondents to take appropriate measures to remove the wattle, eucalyptus trees grown in the forests of the respondent no.3 department in the Western Ghats in the Tamil Nadu region within the time period stipulated by this Hon'ble Court.

ORDER : This petition coming on for orders upon perusing the petition and the affidavit filed in support thereof and upon hearing the arguments of M/S T.LAJAPATHI ROY, Advocate for the petitioner the court made the following order:-

(Order of the Court was made by **R.SUDHAKAR,J.**)

In general, forests stabilize the climate. The plants enrich the soil by recycling the nutrients through the shedding of leaves and seeds. They also regulate the water cycle by absorbing and redistributing rainwater quite equally to every species living within its range, which is known as the economy of water. Thus, forests provide perfect habitats for life to flourish on land. However, it is disheartening to note that the Tropical Montane Evergreen Forests, also known as "*Shola Forests*", are the most threatened ecosystems globally, because of the non-native invasive species. Shola Forests need to be protected. When it is the responsibility of every citizen to work for protection and promotion of forests and greenery by planting more and more trees as contemplated under Article 51-A(g) of the Constitution of India, which is extracted hereunder:

> *'It shall be duty of every citizen of India to protect and improve the natural environment including forests, lakes, rivers and wild life and to have compassion for living creatures.'*

the Courts would be equally zealous in protecting the Shola Forests from non-native invasive plant species. This system of thought led us to pass the order dated 27.2.2014.

2. In the said order dated 27.02.2014, it was very clearly stated that the nature of this writ petition is to restore the Shola forests and its natural habitat. This will help preserve the wild life sanctuaries at different locations in the State. This endeavour is to encourage the growth of indigenous species and remove exotic ones, which even as per the Department Study, are found to be detrimental to the indigenous trees and plants.

3. When the matter was taken up today, it is reported by the District Forest Officer, Madurai District, who is present in the Court, that the wattle and eucalyptus trees, which are exotic species, have the tendency to draw more water for their growth, resulting in reducing the water table. The exotic species does not permit the indigenous species of the Shola forests to survive.

4. Wattle and eucalyptus are commercially exploited for State revenue. The dichotomy between the State revenue and preservation of ecology is, therefore, the ground reality that has to be addressed. Looking at the larger perspective of preservation of forests, more particularly, wild life sanctuaries, the need to preserve and restore Shola forests, other forests and grass lands, etc., which is comprised of indigenous species, will be appropriate for ensuring ecological balance of our biodiversity.

5. This suggestion of the District Forest Officer is the subject matter of a detailed analysis by an Expert Committee which has been formed on the basis of the order passed by this Court on 27.02.2014. Series of meetings have been convened and we have noted it. A resolution for conducting the meeting was taken by the Additional Chief Secretary, Environment and Forests Department, Secretariat, Chennai, on 12.03.2014. In the meeting, the scope of analysis has been segregated as follows:

(a) *Working Plan;*

(b) Government Orders;

(c) Long Term Strategy;

 (d) Supreme Court of India Orders; and

(e) Management Plan in Kodaikanal Division.

Based on that, on 26.03.2014, the following persons were nominated as Members of the said Committee:

Sl.No.	Name and Designation	Position in Committee
1.	Thiru.Basavaraju, I.F.S. Chief Conservator of Forests, (Research)	Chairman
2.	Conservator of Forests, Coimbatore.	Member and Co-ordinator in respect of Nilgiris Hills.
3.	Conservator of Forests, Dindigul.	Member and Co-ordinator in respect of Kodaikanal Hills.
4.	District Forest Officer, Nilgiris North Division.	Member.
5.	District Forest Officer, Nilgiris South Division.	Member.
6.	District Forest Officer, Kodaikanal Division.	Member.

The terms of references of the Expert Committee, are as follows:

"(i) To study the wattle and Eucalyptus menace in the Shola and other forests of Tamil Nadu.

(ii) Suggest possible methods to eliminate the wattle and eucalyptus trees from the forests of Tamil Nadu.

(iii) Post for the conservation, protection and rejuvenation of the forests in Western Ghats Region within the State of Tamil Nadu.

(iv) The Chairman of the Expert Committee may pursue necessary action and issue direction to the Committee members as deemed fit and proper from time to time and sent action taken report to the Principal Chief Conservator of Forests at least on bimonthly basis.

(v) A separate comprehensive study report comprising all the above aspects for restoration Shola and rain forest separately in respect of Kodaikanal and Nilgiris District may be submitted in 10 copies.

(vi) The study report shall consists the entire area of region shola area of the earlier period / shola area in the present / area planted invaded by wattle / eucalyptus and pine.

(vii) Period of operation to replant the area to restore the shola forest and rain forest with indigenous species.

(viii) The study report shall also contains the present methodology and project being implemented and its impact and results.

(ix) The financial implication which includes revenue by the sale of wattle / eucalyptus / pines and also the expenditure for replanting / maintenance with replacement of causality conservation / protection for 2/3 plan period (Working Plan/Management Plan period).

(x) The committee may co-opt any person based on the need for formulation of strategy for eradication of Wattle/removal of Eucalyptus.

(xi) The Committee may also examine the various methodology (removing the seeds at present in the field, clear felling wattle plantations, felling the wattle and eucalyptus plantations and replanting with indigenous species, after removal exotic species, the area may be conserved by fencing to facilitate the natural generalists regrowth of indigenous species and other methods). The plan for removal of wattle/Eucalyptus may be worked out for 2/3 Working Plan/Management Plan Period. Committee may suggest strategy under (a) short strategy (b) Long strategy on scientific ecological principle.

(xii) Any other related issue for removing the exotic species and restoring shola and rain forests."

(extracted as such)

This agenda, by and large, addresses the issue raised in the writ petition for restoring the native Shola forests, forests and grass lands, etc. The Expert Committee met on 11.04.2014 at Coimbatore.

6. It is reported that thereafter another National Workshop was conducted on 13.02.2015 and the issue is under serious consideration by the Committee concerned as well as the Government.

7. The District Forest Officer states that this is the first time such a measure is taken to look at the problem in a different perspective and bring about the restoration of Shola forests, forests, grass lands, etc. by removing the exotic species which even according to the Department, are detrimental to the forests and sanctuaries in many respects. Besides they draw more ground water and deplete the water table. This is causing serious environmental degradation.

8. We also note that there is no reference to alien species or exotic species in anyone of the statutory Acts, namely, the Tamil Nadu Forests Act, 1882, or the Wild Life (Protection) Act, 1972. This is significantly important as the authorities have to assess and formulate schemes for removal of exotic species and to manage and restore the native Shola forests, forests and grass lands, etc.

9. At this juncture, it was brought to the notice of this Court that referring to the order of this Court dated 27.2.2014 and the consequential meetings of the Expert Committee, the First Bench of the Madras High Court, by order dated 17.12.2014 passed in W.P.No.16857 of 1991 (*K.Ussainar v. The State of Tamil Nadu, MANU/TN/3156/2014*) held as under:

"12. The aforesaid thus shows that the Expert Committee is looking into the matter, whose report is stated to be expected soon. The Government Order in G.O.Ms.No. 289, Environment and Forests Department, dated 09.10.2014 has also been issued, allotting 42,594 tonnes of eucalyptus blue gum trees and 27567 tonnes of wattle trees to TNPL from the Nilgiris North Division, to be removed within a period of one year. The area will be restored with indigenous species to its originality and these two trees are stated to be in the process of removal in a systematic manner.

13. Despite the aforesaid, it has been pleaded that permit in Form-I from private area and permit in Form-II under Timber Rules would be required for transportation of wattle trees and bark from the forest area, as the act of peeling off bark is stated to be an act amounting to cutting or causing to cut a tree and the act of peeling off bark is stated to be the death of the wattle trees and such trees may die without corresponding activities for re-plantation of the trees. A comprehensive plan under the forest department is stated to be under consideration and even the removal of wattle trees from the private areas is required to be coded to maintain the eco sensitivity of the area, otherwise the tree cover would be completely wiped out. The problem has been sketched out in paragraph 16 as under:

> '16. It is respectfully submitted that the predominant idea is to remove the exotic species and restore of the grassland. In order to accomplish this goal is rather simple cut the invasive trees and the grasslands will return. In this case, the private land owner is not going to allow grass lands or sholas to come in their own land by removing the exotic species. Any management interventions should be implemented with caution, patience, and initially on a small scale. The landscape is variable, which means different sections on the landscape should get different levels of priority and interventions. Thus, the existing law may be enforced in the private lands and the management of private lands in to its originality with biodiversity is to be planned after the restoration plan in forest areas for a considerable period mixing up will definitely bring malpractices and illegal activities which is injurious to the fragile ecosystem of the Nilgiris.'

1. In the aforesaid conclusion of the factual matrix, it is suggested that since an Expert Committee has already been constituted, the question as to whether wattle bark should be permitted to be removed without the requirement of any regulation may be examined by that Expert Committee itself. Such a course of action is acceptable to both the parties. We are, thus, of the view that this issue, keeping in mind the conspectus of the stand of the two parties, as recorded aforesaid, be referred to the Expert Committee, which would take a considered decision within a maximum period of three months from the date of receipt of the order. In that process, all interested parties, including the petitioner, may be heard and a reasoned decision be taken."

10. In our endeavour to find a solution to this pivotal issue, we leafed through large volumes of materials, and would like to reproduce some of the suggestions given by one Dr.Farshid S.Ahrestani, who is Postdoctoral Scholar, Department of Biology,

Eberly College of Science, The Pennsylvania State University, which in turn are based on our order dated 27.2.2014. An excerpt from the article titled "*To chop, or not to chop? The issue of exotic invasive trees in the Western Ghats*" is as under:

> "**Is there a solution?**
> The petition filed in the courts asks that the Forest Department get rid of the exotic invasive trees to restore the grasslands. The predominant idea to accomplish this goal is rather simple – cut the invasive trees and the grasslands will return. Although there is a poor understanding of the exact mechanism that was responsible for establishing the shola-grassland ecosystem, there is little debate that the process took hundreds, if not thousands of years. Intensive plantation activity for over 40 years, followed by wide-spread invasion by non-native trees for 20 years have surely modified the soils and water tables in the region significantly. Therefore, is it reasonable to expect a system that took thousands of years to evolve, but has been extensively modified for over 60 years, to easily restore itself to a former state? The short answer to this question is "Probably not", which is why we need to acknowledge that we are dealing with a complex issue that probably requires more than the simple solution of chopping down the invasive trees.
>
> **What do we do?**
> There are no clear answers to the restoration process. Any management interventions should be implemented with caution, patience, and initially on a small scale. The landscape is variable, which means different sections on the landscape should get different levels of priority and interventions. The long term needs to be kept in mind – modifications to the landscape lasted 60 years and we have waited twenty years since the end of plantation activity to intervene. We, therefore, need to be patient with the restoration process and not expect large-scale changes in the short-term. Any removal of trees has to be done keeping in mind the needs of the local people for firewood, both for cooking and heating. Unless some effort is made to reduce the dependency that the local people have had on firewood for hundreds of years in the region, we cannot expect this dependency to disappear any time soon. Fortunately the Mukurthi Wildlife Sanctuary in the Niligiri Hills and the Kodaikanal Wildlife Sanctuary in the Palni Hills provide the department with ample opportunity to experiment with management interventions while provisioning for the needs of local people using buffer regions for firewood. For the grasslands to make a comeback they will require assistance and a strong long-term commitment from us. The following suggestions could help address the court order in the short-term and the restoration process in the long-term (the suggestions are targeted at the Palni Hills, but are applicable to the

Nilgiris too):

•*Prioritize the remaining grassland patches:* There are a few remaining grassland patches. These, however, are not completely free of invading non-native trees. Many of these patches are found at the western region of the newly declared Kodaikanal sanctuary, and are far away from human habitation. However, by the same token they are generally difficult to access, often only by foot. Maintaining these remote grasslands patches free of invasive trees and shrubs might turn out to be an expensive endeavour, which requires a strong commitment from the Government to bear these costs.
•*Thinning of plantations:* Shola trees are regenerating within many plantation patches – an invasion of native trees into patches of non-native trees. Ideally we would prefer grasslands to make a comeback, but grasses cannot compete as well as native shola trees can with the invasive trees for sunlight. It makes little sense to kill colonizing shola trees especially since there is no guarantee that grasslands will return to their entire former range. To help shola trees succeed in their colonization, we could help by thinning, i.e., cutting select invasive trees around them. This management intervention is relatively inexpensive and we could experiment with different strategies, i.e., cutting select trees with no additional intervention in some areas, and in others areas cutting select trees, but following up with removal of saplings. Trying different methods will allow the Department to compare the effectiveness and cost to benefit ratios of different intervention strategies.
•*Begin mass tree removal with a pilot phase:*
•Chopping down all the invasive trees would be a staggering endeavour and could lead to further ecological issues. It is common knowledge that large-scale tree removal always affects the soil layer for the worse, either by modifying soil composition or by soil loss. The shola-plantation/grassland landscape plays an important role as a watershed that supplies water to millions of people. It is likely that the plantations have altered the water table for the worse, but it is unlikely that large-scale cutting of plantations would improve the situation. Therefore, it would be best to begin mass tree removal with a pilot phase.
•It would be a good idea to remove trees en masse in 1-2 sizeable (~10 hectares) experimental plots deep inside the Kodaikanal Sanctuary that preferably do not have invading shola tree species (in general, further the distance from a shola patch, less the chance of finding colonizing shola trees). Keeping in mind that this restoration process is meant to benefit wildlife, and that we need buffers of wattle to satisfy the prevailing high demand of firewood, it is important that these plots are not within easy reach of people. It would be best to choose plots that are easily accessible, for example besides a road (an ideal location for both plots would be

around Berijam lake). These plots will require constant support to provide the best conditions for grasses to make a comeback, mainly the regular (every 3-4 weeks) removal of seedlings of non-native trees and native woody shrubs. It is highly likely that supplementary planting of native grasses will be required.

•Based on the lessons we learn from restoring grasses in these initial experimental plots for a period of 2-3 years, we can then expand the scope of removal to other adjacent non-native tree plantations. There are also lessons waiting to be learnt from a few mass tree cuttings that the Forest Department has conducted over the last decade."

This is one suggestion that emanates from a scholar. The restoration of Shola forests, forests and grasslands, etc., has to be considered on the basis of expert opinion, data on impact of exotic species, environmental damage already caused and possible pitfalls in taking up such a project.

11. In the book titled "RAINFOREST RESTORATION - A GUIDE TO PRINCIPLES AND PRACTICE", some of the points which we found of great significance are as under:

"***How do we prioritize areas in the landscape for restoration?***

Sites need to be prioritized for restoration in forest landscapes using specific criteria based on ecological and conservation needs. This could include, for instance:

• sites that are habitats of particular threatened or endemic species,

• stream sides and river courses,

• degraded areas within or along the edges of existing wildlife sanctuaries and reserved forests,

• edges of forest fragments, adjoining plantations or other habitats

• corridors linking forest fragments,

• along linear intrusions such as roads, power-line clearings, and fie-lines, and

• the land matrix (plantations, filds, streams etc.) surrounding fragments or reserves

...

Why should we deal with alien species?

Many alien species (e.g., *Eucalyptus* spp., *Acacia auriculiformis*, *Acacia mearnsii*, pines, *Casuarina equisetifolia*) have been planted widely, even inside wildlife sanctuaries and national parks. In addition, many herbaceous weeds have been introduced and spread due to various human activities and regular small-scale disturbances. Sometimes alien species have been planted as they are considered to provide food for wildlife (e.g., *Maesopsis eminii*). These alien species have various detrimental effects on natural ecological processes, native vegetation, and many wildlife populations through:

• Reduction in ground water table (e. g., *Eucalyptus* spp.)

• Alteration of soil characteristics and microclimate

• Suppression or alteration of native plant communities (e.g., *Maesopsis eminii*)

• Proliferation of other weeds (e.g., *Lantana camara* often grows in the understorey of *Eucalyptus* plantations)

• Change in forest structure and function (many alien species)

• Invasion into surrounding landscape (many alien species, *Maesopsis eminii, Acacia mearnsii, Spathodea campanulata*)

• Reduction in native biological diversity, particularly affecting specialized mature forest animal species

How do we deal with alien species?

A basic principle is that one should strictly avoid planting alien species close to or within wildlife conservation areas. Alien species need to be dealt with care. Most restoration programmes employ means of targeted removal or suppression of invasive alien species. These may include cutting and uprooting of rootstock as in the case of *Lantana camara*, hand-weeding, pressing down of grasses with boards, or even herbicide application on specifi weeds. Care should be taken in such weeding operations not to disturb soil or native vegetation as disturbances can lead to further proliferation of weeds. Occasionally some alien species may prove useful in restoration, if they are noninvasive, by providing partial shade or leaf litter that may act as mulch."

These are questions that have been posed by scholars and nature activists. There is a need to prepare a comprehensive scheme for restoration of native forests and grasslands, etc. Individual countries would have to develop their own model. The trial and error method adopted by different countries can be a pointer for our experts to tread this issue in a meaningful and comprehensive manner.

12. We hope that the officials of the Department will consider the above said materials also and provide answers to these issues and give suggestions for amendment of the relevant provisions of the Act to address the above issues. The effect of damage that is caused by the exotic species to the indigenous trees and plants, should be assessed, controlled or managed or eradicated with an object to restore the indigenous forests and plants for the development of the Shola forests, forests, grass lands, etc. This will restore the wildlife habitat besides helping the climactic cycle and enhance the depleted water resource. **"Save the Shola and Safeguard the Environment"** - is the *mantra* appropriate for the present climatic calamities. There are many Districts in this State that have been

declared drought-stricken. There is hardly any vegetation or agriculture operations. In fact, agrarian economy of India is fast changing. Urban development is the new wave that is changing the social milieu. The forest alone is the buffer to the fast changing rural transformation. These are some of the vital issues to be seriously considered during the course of the Special Committee deliberation for formulating a long term strategy.

13. **We make it clear that in our order dated 27.02.2014, there is no direction as such to cut or remove the exotic species, viz., wattle, eucalyptus trees, etc. All that we said is that a comprehensive scheme has to be prepared in consonance with Section 33 of the Wild Life (Protection) Act, 1972**.

(emphasis supplied.)

14. It is also stated by the District Forest Officer that the restoration of Shola forests, forests and grass lands, etc., has been the subject matter of much debate on various levels throughout the country and the Government has to take a decision in the matter taking into consideration the ecological impact, revenue implication, impact on forest dwellers and forest produce, etc.

15. We agree to the view that it is for the Government to formulate a policy and implement the scheme to protect the indigenous trees and plants and to take steps to prevent the Shola forests, forests and grass lands, etc., from the onslaught of exotic and invasive plant species. The policy should also include restoring the Shola forests, forests and grasslands, etc. This principle may also apply to other exotic plants, shrubs, wild animals, birds and fish, etc. The impact of exotic and invasive species, we find, is very extreme and very costly to reverse. To cite a few examples, Seemai Karuvela trees (*Prosopis juliflora*), rampant in Tamil Nadu and *Lantana (Lantana camara)* (small perennial shrub) in Western Ghat hills - Ottacamand and Kodaikanal. These invasive species out-compete other more desirable species, leading to destruction in biodiversity. It can also cause problems if it invades agricultural land. As a result of its toxicity, it may affect livestock. It has the ability to form dense thickets if left unchecked can greatly reduce the agricultural productivity and destroy farm land, besides affecting very biodiversity and dynamics of that area.

16. Article 48-A of the Constitution of India mandates that 'the State shall endeavour to protect and improve the environment and to safeguard the forests and wild life of the country.'

17. Further, Article 51-A(g) of the Constitution of India speaks about the fundamental duties of citizen in this regard. - 'It shall be duty of every citizen of India to protect and improve the natural environment including forests, lakes, rivers and wild life and to have compassion for living creatures.'

18. We cannot but lay emphasis on this issue any better than the intent stated in the Indian Constitution.

19. Over the last many decades, a number of Forest Invasive Species, without realizing the consequences, have been introduced in

India knowingly or unknowingly. The invasive species are further categorized as floral (weeds and plants having national and regional distribution), entomological (insects) and pathogenic (fungi). Approximately, 111 of such species have been identified across the country under the above mentioned categories. No systematic studies have been carried out so far to inventorize the Invasive Species. However, it would be useful to have a detailed inventory of such invasive species in different ecosystems of Tamil Nadu and in the entire country. Appropriate strategies will have to be devised for their control, eradication and management in connection with various stakeholders and for restoration of endemic native species in a phased manner.

20. The primary concern for the Government is to ensure that any form of exotic varieties of trees, plants, shrubs, wild animals, birds or fish, etc. are systematically removed, so that, it does not endanger the indigenous ones. This aspect of the matter has to be considered by the Government with all earnestness. No doubt, the Department concerned has to make a proposal to the Union Environment Ministry for removal of these exotic species and on such approval of the said proposal, it needs to be placed before the Honourable Supreme Court for final clearance in view of various orders that have been passed in ***T.N.Godavarman Thirumalpad (89) v. Union of India*** reported in ***(2006) 10 Supreme Court Cases 486.***

21. The Honourable Supreme Court in ***T.N.Godavarman Thirumalpad (89) v. Union of India*** reported in ***(2006) 10 Supreme Court Cases 486,*** in paragraph 10, held as under:

> "10. None of the States has filed any objection to the recommendations of CEC made in paras 14 and 15 in relation to clarification about allowing conservation and protection related activities for better management of the protected areas. The recommendations contained therein are, accordingly, accepted and the order dated 14-2-2000 *[T.N.Godavarman Thirumalpad (27) v. Union of India, (2002) 10 SCC 634]* is clarified accordingly. Accepting the said recommendations, we direct as under:
>
> (A) Various activities such as removal of weeds, clearing and burning of vegetation for fire lines, maintenance of fair weather roads, habitat improvement, digging temporary waterholes, construction of anti-poaching camps, chowkies, checkposts, entry barriers, water towers, small civil works, research and monitoring activities, etc. are undertaken for protection and conservation of the protected areas and therefore permissible under the provisions of Section 29 of the Wild Life (Protection) Act, 1972. These activities are necessary for day to day management of the protected areas besides they do not involve any type of commercial exploitation.
>
> The activities abovementioned are permissible under the various provisions of other environmental

laws as well.

(B) The order dated 14-2-2000 *[T.N.Godavarman Thirumalpad (27) v. Union of India, (2002) 10 SCC 634]* will not be applicable to the following activities provided that they (i) are undertaken as per the management plan approved by the competent authority; (ii) are consistent with the provisions of the Wildlife (Protection) Act, 1972; (iii) are undertaken consistent with the National Wildlife Action Plan; (iv) are in conformity with the guidelines issued for the management of the protected areas from time to time; and (v) the construction and related activities are designed to merge with the natural surroundings and as far as possible use forest friendly material.

(a) Habitat improvement activities

Weed eradication, maintenance and development of meadows/grassland required for wild herbivores which are prey base for the carnivores, digging and maintenance of small waterholes and small anicuts, earthen tanks, impoundment of rainwater, relocation of villages outside the protected areas and habitat improvement of areas so vacated.

(b) Fire protection measures

Clearance and maintenance of fire lines as prescribed in the management plan by undertaking controlled cool or early burning and construction of watch towers.

(c) Management of wet grassland habitats

Early or cool controlled winter burning of grassland habitats such as in Kaziranga and Manas National Parks in Assam, to facilitate growth of fresh grass.

(d) Communication and protection measures

Construction of wireless towers, improvement and maintenance of fair weather non-tarred forest roads not exceeding three metres in width, small bridges, culverts, fences, etc.

(e) Anti-poaching initiatives

Construction, maintenance and improvement of small anti-poaching camps/chowkies, patrolling camps, checkposts, barriers, boundary walls, construction of small staff quarters for the front line staff, etc."

and such other order or orders that may be passed from time to time.

22. Recording the above, we adjourn the matter to **12.10.2015**, so as to enable the respondent Department to give us a Status Report on the suggestions that they are coming up with the Management Plan for the Sanctuaries and Working Plan for the Reserved Forests.

23. At this juncture, this Court is only facilitating the concept of Restoration of Shola forests, forests, grass lands, etc., and helping for the indigenous species.

24. List the matter on **12.10.2015.**

sd/-
10/08/2015

/ TRUE COPY /

Sub-Assistant Registrar

TO

1 THE PRINCIPAL SECRETARY
DEPARTMENT OF FORESTS AND ENVIRONMENT, ST. GEORGE FORT, CHENNAI- 600 009.

2 THE PRINCIPAL SECRETARY
DEPARTMENT OF REVENUE, ST. GEORGE FORT, CHENNAI- 600 009.

3 THE PRINCIPAL CHIEF
CONSERVATOR OF FORESTS, GOVT.,OF TAMIL NADU, PANAGAL BUILDING, SAIDEPET, CHENNAI 600 015.

4 THE DISTRICT COLLECTOR
DINDIGUL DISTRICT, DINDIGUL.

5 THE DISTRICT FOREST OFFICER
KODAIKANAL, DINDIGUL DISTRICT

+1. C.C. to M/S T.LAJAPATHI ROY Advocate SR.No.45382

Akm/01.10.2015 /13p-7c/

ORDER
IN
WP(MD) No.3633 of 2014
Date :10/08/2015

[ANNEXURE-G]

BEFORE THE MADURAI BENCH OF MADRAS HIGH COURT
(Special Original Jurisdiction)

Monday, the Twenty Sixth day of October Two Thousand Fifteen

PRESENT

The Hon`ble Mr.Justice R. SUDHAKAR
and
The Hon`ble Ms.Justice V.M.VELUMANI

WP(MD) No.3633 of 2014

M. SARAVANAN ... PETITIONER

Vs

1 THE PRINCIPAL SECRETARY
DEPARTMENT OF FORESTS AND ENVIRONMENT,
ST. GEORGE FORT, CHENNAI- 600 009.

2 PRINCIPAL SECRETARY
DEPARTMENT OF REVENUE, ST. GEORGE FORT,
CHENNAI- 600 009.

3 THE PRINCIPAL CHIEF CONSERVATOR OF FORESTS,
GOVT.,OF TAMIL NADU,PANAGAL BUILDING,
SAIDEPET, CHENNAI 600 015.

4 THE DISTRICT COLLECTOR
DINDIGUL DISTRICT, DINDIGUL.

5 THE DISTRICT FOREST OFFICER
KODAIKANAL, DINDIGUL DISTRICT

6 K.KUMARAN, ... RESPONDENTS

Prayer in WP(MD)No.3633 of 2014:

Writ Petition is filed under Article 226 of the Constitution of India, praying this Court to issue a writ of Mandamus directing the respondents to take appropriate measures to remove the wattle, eucalyptus trees grown in the forests of the respondent No.3 department in the Western Ghats in the Tamil Nadu region within the time period stipulated by this Hon'ble Court.

ORDER: This Writ Petition coming on for hearing on this day and upon perusing the petition and the affidavit filed in support thereof and upon hearing the arguments of Mr.T.Lajapathy Roy, Advocate for the petitioner, and of Mr.M.Govindhan, Advocate for the Respondents 1 to 5 and of Mr.D.Sadiq Raja,Advocate for the 6th respondent and of Mr.M.Santhanaraman, Amicus curiae the Court made the following order:-

(Order of the Court was made by **R.SUDHAKAR,J**)

In our order dated 27.02.2014, we directed the Principal Chief Conservator of Forests, Government of Tamil Nadu, Chennai, to formulate a comprehensive scheme for restoration of Shola Forest, on a systematic removal of wattle and eucalyptus trees. Thereafter, another order was passed on 10.08.2015, based on the in-puts given by the District Forest Officer, Kodaikanal.

2.At this juncture, the District Forest Officer, Kodaikanal, produced a Report of Expert Committee on Comprehensive Study for the removal of alien and invasive species and restoration of sholas and regeneration of grasslands in Nilgiris District in Tamil Nadu, which is submitted by Dr.H.Basavaraju, I.F.S., Chairman of Expert Committee and Additional Principal Chief Conservator of Forests (Wildlife). In this Expert Committee, there is a Sub-Committee for which Mr.D.Venkatesh, District Forest Officer, Kodaikanal Division, is the Chairman. The Detailed Report provides, various technical as well as financial aspects of the project for restoration of shola forest, grasslands, etc. This, according to the District Forest Officer, Kodaikanal Division, has been placed before the Department of Environment and Forest, Government of Tamil Nadu, who have given their approval and then it has been placed before the Finance Department, Government of Tamil Nadu and the Finance Department has also approved it. We record the same.

3.Mr.D.Venkatesh, District Forest Officer, Kodaikanal Division, states that the matter has been forwarded to the Government for its consideration. Taking note of the technical as well as financial aspect of the matter on which the file is resting with the Government for the present, we request the Principal Secretary to Government, Environment and Forest Department, Government of Tamilnadu, the 1st respondent herein and the the Principal Secretary, Department of Revenue, Government of Tamil Nadu, to pursue the matter with the Government and ensure that approval is granted, subject to the evaluation of the report by all concerned. We expect the Government to finalize the report of the Expert Committee, at the earliest. Thereafter, the Government will have to move the Hon'ble Supreme Court, in terms of paragraphs 20 and 21 of our order dated 10.08.2015.

4.The District Forest Officer, Kodaikanal, has also taken pains to address the Court, with photographs, showing restoration of shola forest in certain pockets of Kodaikanal Hills, i.e. Mathikettan Solai, etc., based on the Government's approved scheme, by removing invasive plants. This shows that the Department is aware of the urgent need to restore shola forest and grasslands and to remove invasive and exotic species. Consequent to the shola forest restoration measures taken, wild animals like Nilgiri pipet, porcupine, barking deer, tiger, leopard cat, gaur, etc. are sighted. It shows that there is scope for improving and enhancing shola forest and grassland. We record with appreciation the work already done so far. To enable the respondents to file a comprehensive report on the further action taken, list the matter on 14.12.2015.

5.With the above direction, we adjourn the matter for enabling the Government to file a status report and a comprehensive report on the further action taken. Presence of the District Forest Officer, Kodaikanal, is recorded. His valuable assistance is also recorded and appreciated.

Post the matter on 14.12.2015.

sd/-
Assistant Registrar(Crl.Side)

/ TRUE COPY /

Sub-Assistant Registrar

TO

1 THE PRINCIPAL SECRETARY,DEPARTMENT OF FORESTS AND ENVIRONMENT, ST. GEORGE FORT, CHENNAI- 600 009.

2 THE PRINCIPAL SECRETARY,DEPARTMENT OF REVENUE, ST. GEORGE FORT, CHENNAI- 600 009.

3 THE PRINCIPAL CHIEF CONSERVATOR OF FORESTS, GOVT.,OF TAMIL NADU, PANAGAL BUILDING, SAIDEPET, CHENNAI 600 015.

4 THE DISTRICT COLLECTOR,DINDIGUL DISTRICT, DINDIGUL.

5 THE DISTRICT FOREST OFFICER, KODAIKANAL, DINDIGUL DISTRICT

6 MR.M.SANTHANARAMAN, ADVOCATE-TRUSTEE, WILDLIFE AND FOREST RESEARCH TRUST, NILGIRIS DISTRICT.

Copy to: The Section Officer, Writ Section Madurai Bench of Madras High court, Madurai.

CSL/ARK/AR II/02.11.2015 /3p/8c

[ANNEXURE-H]

For Experts Who Study Coronaviruses, a Grim Vindication

They warned that the next great pandemic would be a coronavirus, but research funding went to studying other threats.

Visual: Undark

BY CHARLES SCHMIDT (HTTPS://UNDARK.ORG/AUTHOR/CHARLES-SCHMIDT/)

06.08.2020

THE NOW PROPHETIC words could be found buried at the end of a research paper (https://cmr.asm.org/content/20/4/660) published in the journal Clinical Microbiology Reviews in October of 2007: "The presence of a large reservoir of SARS-CoV-like viruses in horseshoe bats, together with the culture of eating exotic animals in southern China, is a time bomb."

The warning — made nearly 13 years ago and more than four years after a worrying first wave of severe acute respiratory syndrome, or SARS (https://www.cdc.gov/sars/guidance/core/intro.html), killed nearly 800 people globally — was among the earliest to predict the emergence of something like SARS-CoV-2, the virus behind the current pandemic of Covid-19.

Many other warnings would follow.

Indeed, evidence of a looming and more deadly coronavirus pandemic had been

RELATED

Can Veterinarians Help Prevent the Next Pandemic? (https://undark.org/2020/05/1 animal-medicine-pandemic/)

(https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4797993/) building (https://www.nature.com/articles/nature12711) for years (https://pubmed.ncbi.nlm.nih.gov/26976607/), but experts who specialize in coronaviruses — a large family of pathogens found especially in birds (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6296008/) and mammals that can cross over from other mammals to humans and cause varying degrees of illness — struggled to convince a broader audience of the risk. Dogged by skepticism and inconsistent funding, these coronavirus researchers say they were stymied from developing treatments and vaccines for SARS — many of which could have been helpful in the current crisis. Much about what we learned about SARS would have applied now, according to Michael Buchmeier, a virologist at the University of California, Irvine. "The viruses are so similar."

Those lessons, however, were long delayed — in part because predicting the next pandemic is hard business, and support for infectious diseases preparedness was leaning elsewhere. Both SARS and its far deadlier coronavirus cousin, Middle East Respiratory Syndrome (MERS (https://www.who.int/emergencies/mers-cov/en/)), were understood to be threats. But other coronaviruses cause the common cold, and even the SARS and MERS outbreaks each burned out in less than a year. When those disease cases fell off, public health responders shifted to other viral emergencies such as Ebola and Zika, and coronavirus research funding dropped (https://grantome.com/search?q=coronavirus) sharply.

That left many investigators who had been working on therapies for SARS holding the bag — even as laboratories around the world were reporting ominous findings: A number of SARS-like coronaviruses in bats, they had discovered, were only a few simple mutations away from being able to infect human cells.

Whether the world should have heeded the warnings of coronavirus specialists is, of course, a matter of hindsight. But to some experts whose business it is to hunt potential pathogens before they spillover into human populations, the many years spent not girding for a coronavirus outbreak were tragically — and unnecessarily — wasted.

"We were out there on the ground after SARS working on coronaviruses with Chinese colleagues in collaboration," said Peter Daszak, president of the EcoHealth Alliance, a New York-based non-profit group that took part in a larger, federally-funded effort, called Predict (https://undark.org/2017/05/25/virus-hunters-ebola-usaid-predict/), to hunt for new pandemic viruses in wildlife in 31 countries, including China. That effort was famously defunded last fall, just before the SARS-CoV-2 outbreak began.

"But we were the *only* group of western scientists," Daszak added. "How can we be the only people looking for these viruses when there was such a clear and present danger?"

THE CORONAVIRUS research community has always been small, friendly, and interactive. "A cul-de-sac at the end of the road of virology," says Buchmeier, who's been studying coronaviruses since 1980. Scientists were drawn to the field by a shared fascination: Coronaviruses evolved strategies to protect themselves from genetic errors during replication that are unlike any other in the microbial world.

> *"How can we be the only people looking for these viruses when there was such a clear and present danger?"*

They may induce lethal infections in certain animal species, particularly in cats and pigs. But their reputation in human medicine has long been one of being "wimpy viruses that cause only mild disease," said Albert Osterhaus, founding director of the Research Center for Emerging Infections and Zoonoses, in Hanover Germany. So, when SARS emerged in late 2002, he added, there was initially "general disbelief among medical people that a coronavirus could be the basis of such a huge outbreak."

As the epidemic spread, an influx of new researchers crowded the field. More grants were awarded and the funding started to climb. "Everyone wanted to know where the virus had come from," said Ralph Baric, a microbiologist at the University of North Carolina Gillings School of Public Health. Initial findings pointed to wild civets and racoon dogs sold for meat and pelts, respectively, in Chinese markets. Later evidence began to implicate horseshoe bats as the original source of the infections. Some researchers whose careers before SARS were grounded in basic coronavirus biology began working on therapies and vaccines — and they made steady progress for several years.

But after increasing from a low of 28 in 2002 to a peak of 103 in 2008, the number of grants funded by the National Institutes of Health for coronavirus research went into a tailspin. "Also, the people went away," said Susan R. Weiss, a virologist at the University of Pennsylvania's Perelman School of Medicine. "They rush in and they rush out."

To be sure, some researchers working with larger, multi-investigator grants retained their support. Baric and his collaborator Mark Denison at Vanderbilt University, for instance, kept their funding and went on to repurpose remdesivir, originally developed to treat hepatitis C, but now the first approved drug for Covid-19 for emergency use.

But according to Linda Saif, a virologist and mucosal immunologist at Ohio State University, in Wooster, the funding declines hobbled individual investigators who weren't part of these larger consortia. Pharmaceutical companies that develop vaccines and therapies scaled back on coronavirus research, too, and within just a few years after the SARS outbreak, public health funding agencies both in the United States and abroad "no longer regarded coronaviruses as a high public health threat compared to other diseases," Saif wrote in an email to Undark.

Saif herself had been studying the respiratory consequences of giving steroids to coronavirus-infected pigs, whose symptoms mirror those of SARS patients. After coronavirus was deemed not to be a significant human pathogen, "it was very hard to get funding to keep going in that area," she said. Another similarly affected researcher was Brenda Hogue, a virologist at Arizona State University, in Tempe. Hogue had devoted her career to studying coronaviruses, focusing on the protein machinery that drives their assembly. After SARS, she and her colleagues turned part of their attention towards developing a vaccine. But when the funding dropped off in 2008, the vaccine went into limbo "and we put our efforts into other directions," Hogue said.

Though support for coronavirus research spiked a bit with the MERS outbreak in 2012, the increase was short-lived. Since the outbreak was quickly contained, the disease didn't raise wider concerns, and grant opportunities declined further.

IRONICALLY, just as funding for drugs and vaccines was drying up, evidence that other coronavirus threats lurked in wildlife was only getting stronger. Scientists had for years been finding viral strains in bats and other animals that were genetically similar to the virus behind the SARS epidemic. But sequence data has its limits. To demonstrate that a virus is actually harmful to people, scientists need to isolate and culture the microbe and show it infects human cells in the lab. Coronaviruses initiate infections by using the spikey proteins jutting from their surfaces to bind with receptors on their target prey. And SARS-CoV uses its spike protein to bind with a specific receptor called ACE2, which normally helps to regulate blood pressure.

Ten years would pass, however, before researchers could show there were other SARS-like viruses in nature that also bind with ACE2. The evidence came from a team based at the Wuhan Institute of Virology, which was the first to isolate a SARS-like virus from horseshoe bats. Led by virologist Zheng-Li Shi, the Wuhan team reported (https://www.nature.com/articles/nature12711) in 2013 that this particular virus, called WIV1, binds with ACE2 in civet and human cells, and then replicates efficiently inside them. "That was the red flag," Saif said. Earlier evidence suggested that direct contact with these bats could lead to viral spill over in humans. "Now there was proof of that."

The bats had been trapped in a cave in Kunming, the capital of Yunnan Province. At least seven other SARS-like strains were present in that same colony, leading the researchers to speculate that bat coronaviruses "remain a substantial global threat to public health."

In addition to culturing WIV1, the Wuhan team also sequenced two other SARS-like strains in bat feces, including one called SHC014. They didn't culture the microbe, but Baric and his colleagues did explore its infectious potential with an experiment: They created a hybrid microbe by attaching the spike protein from SHC014 to the genetic backbone of a SARS-like virus that was previously adapted to grow in mice. Called a chimera — an organism containing cells with more than one genotype — this lab-made microbe had no problem binding with ACE2 and infecting human cells. Baric's research team concluded that like WIV1, any SARS-like viruses outfitted with the SHC014 spike could pose cross-species threats to people.

Some conspiracy theories currently circulating (https://www.the-scientist.com/news-opinion/theory-that-coronavirus-escaped-from-a-lab-lacks-evidence-67229) allege that a chimera may have escaped from high-security labs at the Wuhan Institute of Virology and caused Covid-19 — and Baric acknowledged the risky nature of the research. "In general, we don't know the transmissibility or virulence potential of any bat viruses or chimeras," Baric said in an email message. "Hence it's best to keep and work with them under biosafety level 3 laboratory conditions to maximize safety."

Still, Baric points out that a chimera would display a genetic signature "that says what it is." The adjoining parts of a chimera segregate discreetly in a logical pattern. A genetic analysis of the chimera produced in his lab, for instance, "would come out to be mouse-adapted SARS everywhere but the spike, which is SHC014." Similar logical patterns are absent in SARS-CoV-2, indicating that the virus evolved naturally.

Conspiracy theories aside, even as Baric and others were generating lab evidence that more SARS-like viruses were poised for human emergence, another outbreak — in pigs, not people — provided another strong and recent signal: Some 25,000 piglets (https://www.nature.com/articles/s41586-018-0010-9) were killed by a coronavirus in Guangdong Province, China, starting in 2016. That virus, too, was found in horseshoe bats, and Buchmeier describes the outbreak as both a major cross-species spill-over and a warning shot that was never really picked up by the broader public health community.

"They called it an agricultural virus," he said, "and didn't consider it as predictor of something that could happen in a human disease."

BUCHMEIER emphasizes that responders could have devoted more efforts to look for coronaviruses (https://undark.org/2020/05/18/human-animal-medicine-pandemic/) in animal markets following the outbreak in swine. But as fate would have it, funding trends were headed in precisely the opposite direction. Federal funding for the Predict surveillance program was terminated in September 2019, only months before the Covid-19 pandemic began.

The EcoHealth Alliance, which had been part of the Predict effort, maintained its own collaboration with the Wuhan Institute of Virology using funds supplied by the National Institutes of Health. But on April 24, the Trump administration — which is investigating whether SARS-CoV-2 escaped accidentally from the Wuhan Institute, an allegation that's been broadly discredited — directed (https://www.npr.org/sections/goatsandsoda/2020/04/29/8479482 the-u-s-government-stopped-funding-a-research-project-on-bats-and-coronaviru) the NIH to cut off that support.

Then on May 12, The Wall Street Journal reported (https://www.wsj.com/articles/china-stalls-global-search-for-coronavirus-origins-wuhan-markets-investigation-11589300842) that the Chinese government was responding in kind, "by stalling international efforts to find the source of the [SARS-CoV-2] virus amid an escalating U.S. push to blame China for the pandemic."

To disease experts, the bickering is a worrying — perhaps even astonishing — indicator that at least some global leaders still aren't hearing what they have to say about the threat of coronaviruses, and Baric asserts that the ongoing pandemic exposes the need for better communication between countries, not less. "That is absolutely key," he said. "Critical information needs to be passed as quickly as possible."

The same, many scientists argue, might be said for the dialogue between public health responders and microbiologists. Had new SARS-like viruses been met with the appropriate level of urgency, Ohio State's Saif says, then the coronavirus community might have been farther along with approaches for defeating them, and SARS vaccines that were already tested for safety could have advanced to the next phases in clinical trials, including investigations of their capacity to protect against infection.

As it stands, coronavirus research is now spiking again with Covid-19. Congress approved (https://www.sciencemag.org/news/2020/03/massive-us-coronavirus-stimulus-includes-research-dollars-and-some-aid-universities) nearly $1 billion for vaccine, anti-viral, and diagnostic research as part of the $2 trillion Coronavirus Aid, Relief, and Economic

Security Act, which was authorized in March. Much of the money is going to the pharmaceutical companies developing these products, according to Saif. The National Institutes of Health is also busy channeling both its regularly appropriated funds along with emergency disbursements toward nearly $1.8 billion in Covid-19-related projects and programs, all under an accelerated protocol, according to NIH's deputy director for extramural research, who outlined the funding streams (https://nexus.od.nih.gov/all/2020/04/13/covid-19-funding-and-funding-opportunities/) in a blog post in April.

To Osterhaus, this is both good news and a familiar scenario. Too often, he says, money follows infectious disease outbreaks instead of being out in front of them "as a protective wall." That's certainly true of the Covid-19 pandemic today, he said, suggesting that policy outcomes could have been different.

"It would have been appropriate to take warnings from coronavirus researchers more seriously," he said. "We could have better prepared."

UPDATE: A previous version of this story incorrectly suggested that the swine flu outbreak in Guangdong province, China occurred in 2018. It began in 2016.

Charles Schmidt is a recipient of the National Association of Science Writers' Science in Society Journalism Award. His work has appeared in Science, Nature Biotechnology, Scientific American, Discover Magazine, and The Washington Post, among other publications.