Review Article
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The Link between Biodiversity Degradation and Zoonotic Diseases

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Abstract

According to the World Health Organization (1959) "Zoonoses are diseases and infections which are naturally transmitted between vertebrate animals and man". Today, about 60% of all infectious diseases are zoonoses and more than 75% newly emerging infectious diseases originate in animals and 71% of the total events of emergence of infectious diseases originate in wildlife and disease emergence is considered to have a close association with biodiversity. Biodiversity is often understood in terms of the wide variety of plants, animals and microorganisms, the genes they contain and the ecosystem they form- a result of billions of years of evolution. There are increasing researches showing that higher biodiversity markedly reduces the rates of pathogen transmission thereby arresting the numbers of spill-over events lowering the emerging zoonoses risks for human beings. The most studied inhibitory effect of increased biodiversity on pathogen transmission or spill over is known as "dilution effect." Several anthropogenic and so-called developmental activities cause the degradation of biodiversity thereby reducing the dilution effect resulting increased risk of spillover events and disease emergence. To mitigate the occurrence of these dreadful events in future conservation of biodiversity is needed.

Keywords: Biodiversity degradation, Emerging zoonoses, Anthropogenic activities, Zoonotic spillover

Introduction:

Zoonosis is a much-talked subject to the present-day public health experts. It has received more intensive attention once the universe has experienced the horror of COVID 19. Spillover of diseases are not a new thing, rather it has a long past. Recent literatures in relation to the diseases transmitted between vertebrate animals and man (zoonoses), strongly suggest that the number of spillover events are on the rise since the middle of 20th century. A total of 335 events of disease emergence occurred between 1940 to 2004 were studied by a group of scientists led by Jones E. Kate. Their observation revealed that the disease spill over events are highly associated with emergence of zoonotic diseases and about 71% of the total numbers of disease emergence is of wildlife origin and somehow linked to the degradation of biodiversity through different anthropogenic activities (Jones et al., 2008). Researchers from all over the world have also identified thousands of microorganisms representing from viruses, bacteria, and fungi those are originating from animals especially from wildlife are having spillover potential and are spread over almost all continents of the globalized world (Carlson, 2020). Because 60 % of all known infectious diseases of human being are of animal origin and among the newly emerging infectious diseases 75% are of animal origin (Vidal John, 2020), it is high time to be on high alert for setting proactive holistic approach towards the mitigation of this global challenge.

Although different developmental activities at all levels should be put on right track, at the same time it is also important to do it in the context of the recent pandemic. We should not ignore the lessons that we have learnt out of it and consider it as an opportunity to use all our natural resources in a sustainable way for gaining maximum benefits.

Zoonotic Diseases:

Sometime between 1880 to 1885, Rudolph Virchow, A German physician, and pathologist, while working on a pig parasite *Trichinella*, for the first time coined the term 'zoonosis'. He also made a famous remark out of his wisdom that "between animal and human medicine there are no dividing lines-nor should there be." About 75 to 80 years of using this term by Dr. Virchow, the World Health Organization (WHO) in 1959 for the first time defined the term 'Zoonosis'. According to the WHO "Zoonoses are diseases and infections which are naturally transmitted between vertebrate animals and man" (NCDC, 2016). More than 100,000,000 of cases and 1,000,000 of deaths across the world occur every year from zoonoses (Nair, 2020) and the most concerning part is that, in most of the emerging zoonoses we do not have any medicine or vaccine to restrict its spread.

Impact of zoonoses:

The impact of zoonoses could well be realised by the human civilization during the COVID19 pandemic. In fact, the spread of this pandemic has brought the global economy to its knees. COVID-19 has significantly wedged all sectors of the society including health and education sectors, financial sectors, travel and hospitality sectors, and the sports sector (Ozili and Arun, 2020). Travel industry is poised to lose significant revenue due to the pandemic (Ozili and Arun, 2020). The pandemic with its innate nature stifled the human civilization up to every nook and corner by two methods: first, the spread of the virus encouraged social distancing which led to the closure of economic markets, corporate offices, businesses, and events. Second, the augmented rate at which the virus was dispersing, and the amount of uncertainty about how bad the situation could get, led to sudden shift to safety in consumption and investment among consumers, investors and international trade partners. It is estimated that millions of people will face extreme poverty due to the stalled growth resulting from this pandemic (Ozili and Arun, 2020).

Zoonotic diseases or similar kind of emerging infectious diseases hugely affect the travel industry. One of such many examples is COVID 19 pandemic. The International Air Transportation Association (IATA) stated that the air travel industry would lose US$113 billion if the COVID-19 outbreak was not quickly contained. The losses are encountered due to increased flight cancellations, cancelled hotel bookings and cancelled local and international events, imposition of stay-at-home policies etc. It also impacts on sports and similar events. Different mega sport events linked to football, formula one, hockey, rugby, cricket, baseball, lawn tennis, motorsports and many more were either suspended or delayed due to COVID 19 pandemic. The Tokyo Summer Olympic and Paralympic games were also postponed. Different events industry was hit financially by many cancellations — exhibitions, live music shows, conference, weddings, parties, corporate events, brand launches, trade shows, and more. The global film industry incurred a $5 billion loss during the corona virus outbreak. The International Alliance of Theatrical Stage Employees (IATSE) reported that an estimated 120,000 down the stream auxiliary industry jobs were lost due to the pandemic, most of which were theatre-stage employees. The worst affected sector was the education sector. The COVID 19 also disordered the $600 billion higher education business. Persons related to this field all over the world felt the ripple effect of the pandemic as educational institutes were instructed to shut down after the corona virus was declared a public health emergency in many countries. The outbreak had a more severe consequence on schools that did not have an online learning platform (Ozili and Arun, 2020).

Emerging zoonoses and the cross-species transmission (spillover):

Many a times, ‘spillover’ or cross-species transmission has been found to be an important instrument in the emergence of zoonotic diseases. It can be defined as the “cross-species transmission of a parasite into a host population not previously infected” (Ellwanger and Chies, 2021). To emerge a pathogen through spillover, it needs to overcome two distinct ecological barriers namely **transmission barriers** and **species barriers**. Important routes to overcome the transmission barriers are direct contact, indirect contact, airborne transmission, oral ingestion and through bites of arthropod vectors. When organisms are there within the animals, may be domestic or in wildlife, they form the pathogen pool. And the very few organisms from the pathogen pool who qualify to cross the transmission barriers will form the propagule pool. Now organisms from this propagule pool need to cross the species barrier. Crossing this species barrier is again governed by several factors like phylogenetic distance between the source and the recipient host species, spatial distance naturally maintained between the animal species and human, pathogenic diversity hosted by the animal species etc. Again, the very few negligible numbers of organisms those qualify to cross the species barrier will form the zoonotic pool to spill over to human host resulting a new episode of zoonotic emergence. In the past 100 years, the emergence of zoonotic diseases has accelerated. The 2020 Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) workshop report on biodiversity and pandemics reviewed scientific evidence which demonstrated that pandemics are becoming more frequent. They reported that the menace of pandemics is growing rapidly with more than five new diseases evolving in people every year, any one of which has the capacity to spread and become pandemic (Bedenham et al., 2022).

Biodiversity its concept, importance, and threats:

Biodiversity is a wide-ranging umbrella term that denotes the variety of different forms of life on earth, including the different kinds of plants, animals, micro-organisms, the genetic materials they contain and the ecosystem they build up. It is a result of billions of years of evolution. In other words, biodiversity is the food we eat, the water we drink and the air we breathe. More precisely, it is the part of us, as we humans are part of nature. It is assumed that around 52 million species may be there on earth, of which only 2.1 million are known to man (Mora et al., 2011). Biodiversity can be classified as Genetic Diversity (variation of genes within species and populations),

Species Diversity (variety of species or the living organisms) and Ecosystem Diversity (variety of habitats, biotic communities, and ecological processes). Again, Species Diversity is of two kinds namely *Species Richness* (total count of species in a defined area) and *Species Abundance* (relative numbers among species). It provides us with several utilitarian benefits in the form of agricultural materials (all kinds of foods both plant or animal origin), medicines, industrial raw materials; ecosystem services by mitigating climate change, maintaining CO2 and O2 balance, regulating biochemical cycles, removing pollutants and waste materials, ecosystem resilience and also providing ethical and moral benefits and aesthetic values in human life. Following are some of the amazing facts those are reinforcing the undoubted role of biodiversity in our life (Day et al., 2012):

- Some 200 million people depend on wild species for at least part of their food.
- Even in USA, the most technologically advanced country half of the 100 most prescribed drugs originate from wild species.
- 80 % of people live in Africa rely on traditional medicines as main source of their health care need.
- Microbes have given us nearly all of our antibiotics.
- One third of the world's food, worth over US$ 190 billion per year, depends directly or indirectly on pollination carried out by insects, bats, or birds.
- A single colony of Mexican Free-tailed Bat eats more than 9,000 kg of insects per night targeting especially major crop predators.
- A single brood of woodpeckers can eat 8,000 to 12,000 harmful insect pupae per day.
- Frogs provide a range of pharmaceutical compounds starting from pregnancy test kit, antibacterials, antifungals, painkillers and even mosquito repellants attracting the species name "Hopping Pharmacy."

However, species extinction is a natural part of Earth's history but human activity has increased the extinction rate by at least 100 times compared to the natural rate. A square kilometer of coastal ecosystem such as mangroves forests can store up to five times more carbon than the equivalent area of mature tropical forests. But world mangroves are being destroyed 3 to 4 times faster than forests increasing more and more carbon accumulation (IUCN: facts and figures on biodiversity, 2012). As rate of extinction of species is a key indicator of the health of a biosphere, which is again linked to the health of people, the present rates of species extinction, which are 100 times, and in some cases 1,000times or more, faster than those observed in the fossil record is of great concern (Pimm et al., 1995). Biodiversity is declining rapidly due to factors such as habitat alteration and destruction by the land use change, over exploitation of biological resources, climate change, pollution, and invasive species. Such natural or human-induced factors tend to interact and amplify each other (Rawat and Agarwal, 2015). As species extinction events are happening in an unprecedented rate in human history, both researchers as well as policy makers are more and more focused to find out how the variety, distribution, and abundance of life that is biodiversity on a particular landscape are influencing health as well as the zoonotic disease transmission in that area.

Biodiversity loss and zoonotic diseases:

Thousands of infectious agents circulate in human population. Many of them at time circulated in other vertebrate animals where they might have caused diseases to their natural hosts or simply without causing any harm to them. Irrespective, at a certain point they spilled over into human and started to cause diseases. In present time, there is a tendency among the workers to work on zoonotic viruses among the microbes because they are considered as the most likely to cause emerging zoonotic diseases. Initially, there was confusion over the role of biodiversity in pathogen transmission. It was thought that virgin natural areas with high biodiversity were seen as likely sources of new zoonotic pathogens, suggesting that biodiversity could have negative impacts on human health. Later biodiversity has been recognized as potentially benefiting human health by reducing the transmission of some pathogens that have already established human populations themselves in. This apparently opposing effect of biodiversity in human health was due to the different alternative conceptual models used by the researchers linking host diversity to zoonotic emergence in humans. Researchers from the former group used the ***"Total Host Diversity"*** model, where the overall host diversity of a particular area were considered as a source of pathogen pool, any one of which could jump to humans resulting an event of spillover. Whereas, the second alternative model which is also known as ***"Zoonotic Host Diversity"*** model presumed that not all the other vertebrates-rather certain groups- such as bats, rodents, or livestock- might be significantly more likely to act as sources of zoonotic diseases. And in the third alternative model named ***"Zoonotic Host Diversity and Abundance"*** model considered both the diversity and the abundance of the animals most likely to act as hosts for zoonotic pathogens were critical. The last two models were gained more confidence among the researchers when it was also evidenced by different researchers that not all the taxa are equally capable to transmit zoonotic diseases, rather some are more likely to do so. Different research groups have identified different vertebrate taxa as the more likely to transmit pathogens to humans. For example, ungulates

followed by carnivores and bats (Woolhouse and Gowtage-Sequeria, 2005), bats (Dobson et al., 2005), rodents followed by bats, carnivores, ungulates and primates (Johnson et al., 2020) and few of them identified rodents as the group hosting the greatest number of zoonotic viruses (Johnson et al., 2020 and Mollentze and Streicker, 2020). Some of the researchers also proposed domesticated species to act as a "bridge host" for zoonotic pathogens where they transmit the pathogens after acquiring them from the wild hosts (Borremans et al., 2019). But, finally these are the five Orders of mammals namely Primates, Cetartiodactyla, Carnivora, Rodentia and Chiroptera who have been considered as the most common sources for zoonotic pathogens and thereby the "Total Host Diversity" model lost its appropriateness.

Once it was evident through different studies that some of the vertebrates were more likely to act as the source of zoonotic pathogens, researchers started to find out the effects of different anthropogenic activities on those zoonotic hosts. Interestingly it was observed by some scientists that species that host zoonotic pathogens were more likely to be of lower conservation concern that means they were more abundant (Johnson et al., 2020). They suggested that there was a positive correlation between the zoonotic host status and the resilience to anthropogenic activities like change in land use pattern, overexploitation in the form of hunting, trade, pollution, intrusion of invasive species etc.

In one study, the effect of human impacts on host diversity and abundance was analyzed and reported that wild species known to be zoonotic hosts were more abundant and more diverse (as measured by species richness) inhuman-impacted habitats compared to less disturbed habitats. In contrast, wild species not known to be zoonotic hosts declined in diversity and abundance in human-impacted habitats (Gibb et al., 2020). Mendoza et al., 2020 came to a similar conclusion using a smaller dataset of ecological communities and zoonotic hosts.Gibb et al., 2020 also provided evidence that the diversity and abundance of animals in human-impacted habitats shifts toward species that are more likely to be competent zoonotic hosts. In this way, the "zoonotic host diversity and abundance" model became a more realistic than the other two models.

It was further reported by the scientists that zoonotic reservoirs have significantly "faster" life histories – including shorter gestation periods, larger litters, lower neonate body mass and younger age at sexual maturity – compared to non-reservoirs (Plourde et al., 2017; Steams, 1976). To explain this typical association researchers suggested that there is a trade off in investment in innate versus adaptive immunity, with shorter-lived species investing more in the former while longer lived species invest more in the latter (Streicker et al., 2013). That means mammal species that harbor a greater number of pathogen species are more abundant in human impacted habitats and there may be mammalian traits that impact both tolerance to human disturbance and tolerance to infection (Gibb et al., 2020).

It is evident through scientific research that when biodiversity is lost from ecological communities, the species most likely to disappear are large-bodied species with slower life histories (Hutchings et al., 2012), while smaller-bodied species with fast life histories tend to increase in abundance (Keesing and Young, 2014). Recent research shows that fast-lived species are more likely to transmit zoonotic pathogens (Plourde et al., 2017). Together, these processes are likely to lead to increases in the abundance of zoonotic reservoirs when biodiversity is lost from ecological systems. Taking deforestation or fragmentation of forest as one of many important anthropogenic activities that causes the loss of biodiversity the above situation can be well explained. The undisturbed intact forest ecology can well support all the habitats in their own areas, i.e., the larger sized animals into the deep core forests and smaller in the periphery which is called the edge of the forests. Now, fragmentation of forest will reduce the area of core forest and at the same time increase the edge area of the forests resulting in the decline of the numbers of large-bodied species and increasing the numbers of smaller-bodied mammalians ultimately declining the biodiversity. This is called "edge effect." And as because of fast-lived smaller – bodied species are more likely to transmit zoonotic pathogens, there is increased possibility of occurrence of spill over events. At the same time, in a more diversified ecosystem, the same sized pathogen pool had a much wider scope to be diluted ('dilution effect') among the both efficient as well as the inefficient hosts rather than a less diversified efficient host ecosystem resulting in a better disease transmission scenario. Therefore, any anthropogenic activities like deforestation, intensive agriculture, fossil fuel extraction, mining, and other types of land use changes that causes biodiversity losses ultimately causes the loss or reduction of dilution effect increasing the risks of spillover events and zoonotic disease emergence.

Conclusion:

Following strategies may be prioritized for mitigation of the zoonotic spillovers in relation to the biodiversity degradation-

1. First, we should recognize zoonoses as a problem through understanding the health as well as socio economic consequences of these diseases.

2. We should also understand that the degradation of biodiversity across the globe is the main factor associated with the emergence of zoonotic diseases.
3. We should find out the diverse communities of host species serving as a source of new pathogens.
4. As viruses have been recognized as the most likely pathogens to cause disease emergence, detection, and identification of potential zoonotic viral threats to human health and food security is to be done.
5. Determination of geographic distribution and ecologic scopes of those viruses to inform risk and surveillance in human and animals is the need of the hour.
6. Monitoring of the movement of detected viruses across hosts and regions is to be done.
7. Improving the assessment of the risk of spillover and epidemic potential and forecasting to prevent the possible epidemic.
8. Conservation of biodiversity by using different in-situ as well as ex-situ conservation methods.

Conflict of interest:

The authors declare that no conflict of interest exists.

Author's contribution:

CD prepared the manuscript and RaB and RB critically reviewed the same.

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