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How does Agricultural Expansion Affect Nipah Virus Ecology?

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Abstract. In locations experiencing rapid agricultural expansion, the Nipah virus is an emerging zoonotic pathogen that brings about a serious threat to public health. This study looks at the effects that agricultural expansion has on the ecology of the Nipah virus. The study examines the consequences of habitat loss on fruit bat populations, the natural reservoir hosts for the Nipah virus, and how these changes influence bat foraging behaviour and interaction rates with other living organisms. Through reviews of outbreak data, the research identifies a link between agricultural activities and the increased risk of Nipah virus spillover into populations. The findings suggest that the expansion of agriculture disturbs the natural habitats of bats, forcing them to forage near humans and livestock which encourages the virus's spread. The results emphasize the importance of strategies for agricultural biosecurity, wildlife conservation, and land-use planning in order to minimize the potential for Nipah virus outbreaks.

Keywords: Nipah virus, agricultural expansion, transmission, zoonosis.

1. Introduction

Nipah virus, belonging to the genus Henipavirus of Paramyxoviridaes subfamily [1], first outbreak in a Malaysian village in 1998 to 1999 [2], causing fatal encephalitis and acute respiratory illness. It is a zoonotic and occasionally a person-to-person transmitted viral disease that presents a high mortality rate [3] and is considered to have a pandemic potential. The natural reservoir is fruit bats of Pteropus; they remain asymptomatic while carrying the virus. Infection of this disease may result from direct contact with excretions or secretions of infected animals including fruit bats and pigs. In humans, clinical features present with fever, headache, dizziness, vomiting, diarrhoea, and myalgia with more significant signs including encephalitis, acute respiratory distress syndrome, and several neurological features [4]. In recent years, the majority of outbreaks occurred in Southeast Asia, specifically in Bangladesh, Malaysia, and India.

Agricultural expansion, including deforestation and land conversion of natural habitats into agricultural land, and improved crop yields, have been highlighted as an important factor for the transmission of zoonosis [5]. These agricultural practices bring humans and wildlife closer with more frequent interactions, directly changing the way pathogens are spread among populations.

The Nipah virus poses a serious risk to public health. However, due to multiple factors, vaccinations are currently unavailable for human and livestock populations. Prevention techniques such as avoiding contact with infected hosts and practising good hygiene are more productive and economical than vaccinations [6].

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In this review, we describe the ecology and the mode of transmission of Nipah. We discuss past outbreak cases in Malaysia, Bangladesh, and India, and recent agricultural practices to describe the connections between agricultural expansion and the habitat and behaviour of the Nipah virus in livestock farms.

2. Nipah Virus Ecology

Pteropus vampyrus and Pteropus hypomelanus have been found to be the natural reservoirs of the Nipah virus [1]. They are widespread in tropical regions of Asia, East Africa and Australia [7], while playing a role in seed dispersal [8]. These flying foxes do not exhibit symptoms of the Nipah virus infection while carrying and spreading it to other organisms through saliva, urine, or faces. In the Malaysian infections, pigs were infected and manifested clinical symptoms. Although dogs and horses were also infected, they were dead-end hosts [9], whereas pigs served as amplifying hosts [1].

Transmission of Nipah virus generally occurs through direct or indirect contact with contaminated materials. A transmission from bats to pigs and then pigs-to-human may occur, where after infecting the virus, pigs animals can serve as secondary hosts and spread the infection to people [10]. For human-to-human transmission, it can result in nosocomial epidemics in healthcare settings when close contact with an infected patient's body fluids develops. Humans may also acquire the disease by eating fruits that have been partially consumed by fruit bats carrying the disease [7].

The symptoms depend on the severity and progression of the Nipah virus. It often begins with non-specific prodromal signs such as fever, headache, dizziness, vomiting, nonproductive cough, and myalgia [3]. In severe cases, neurologic signs appeared, including altered consciousness, cerebellar dysfunction, myoclonus, areflexia, hypotonia, hypertension, and tachycardia [7, 11]. Respiratory symptoms, including acute respiratory distress syndrome, occur in severe cases. Survivors may experience relapses, severe chronic sequelae, neurological deficits, and other psychiatric complications such as depression and personality changes [3].

3. Past Outbreak Cases

3.1. Malaysia 1998 to 1999

This zoonotic virus first appeared in Kampung Sungai Nipah (Nipah River Village) in Malaysia, hence giving the name "Nipah Virus" [8]. During the first outbreak from 1998 to 1999 [2], Classical Swine Fever and Japanese encephalitis [3] were suspected to be the cause of infections separately in pigs and humans before the Nipah virus was identified. The outbreak resulted in 265 cases with 105 deaths with an overall case-fatality rate of 39.6% [8, 12]. However, there's only a high mortality rate present in human infections, with a relatively low mortality rate in pigs. About 70% of patients work directly in pig farms [8], therefore one million pigs [13] were culled in order to control the spread of the virus in Malaysia.

Infected pigs manifested mild respiratory symptoms such as nonproductive coughs and neurologic signs including tremors and ataxia [7]. The virus was spread through direct contact with nasal discharge and aerosolisation by coughing of infected pigs [1]. The pharyngeal and respiratory secretions may have explained the large number of respiratory symptoms exhibited after infection.

The spillage might have been caused by deforestation, drought, mixed agro-pig farming techniques, and traditional pig sty designs [9, 12, 14]. Pigs on the same farm spread the illness by contact with porcine fluids. Spillover between pig farms occurred as a result of pig mobility and farm proximity [15]. Although there weren't many human-to-human cases observed in Malaysia [16], pig-to-human transmission was common as it developed from close contact with pigs during farming activities [12, 17].

3.2. Bangladesh 2001 and 2003

During the year 2001, in Meherpur, Bangladesh, the Nipah virus spread rapidly for the first time in this country within a month [13]. 13 cases were identified, and the 9 patients with probable cases all died

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after being hospitalised. Patients died ranging from 3 to 10 days after onset of the Nipah virus. Later, in 2003, Naoganon, a village close to the village in Meherpur, reported death and investigations revealed a similar outbreak of Nipah virus. A result of 12 cases were identified and 8 patients died within on average 4 days after the discovery of infection. Altered levels of consciousness, headache, coughing and difficulty breathing were common manifestations among these infected individuals [18].

There may be potential sources of zoonotic transmission from livestock to humans, but none were tested in Bangladesh for both epidemics. Unlike the situation in Malaysia, human-to-human transmissions were suggested instead of a secondary animal host being identified [4]. About half of the infections resulted from close contact with infected patients, particularly in healthcare settings or during caregiving.

According to Luby et al.'s study, the transmission was due to the ingestion of contaminated raw date palm sap by Pteropus fruit bats [19]. Bats frequently lick or urinate into collecting pots placed on trees to collect sap, thereby spreading the virus [13]. The virus's ability to withstand changes in pH and a minimum of seven days at a temperature of 22°C in date palm sap (Rahman et al.) [20] may be responsible for the high number of infections.

3.3. India 2001 and 2018

Nipah virus took a major outbreak in Siliguri, West Bengal, India, in 2001 through nosocomial transmissions [4]. A result of 74% case-fatality was shown with the identified 66 cases of encephalitis in Siliguri, again demonstrating the alarmingly high fatality rate of the virus. Rather than a pig-to-human transmission of the Nipah virus, human-to-human transmission was mainly documented [4], where 45 patients had hospital exposure. The Nipah virus was analysed using the reverse transcription-polymerase chain reaction method due to Siliguri's close proximity to Bangladesh. The results showed that the virus strain was more closely linked to the Bangladesh NiV-B strain than the Malaysian NiV-M strain, suggesting that there wasn't a distinct animal host involvement [8]. Common symptoms that appeared were altered sensorium, headache, myalgia, and respiratory symptoms, while fever was the one that occurred in every patient. 10 patients died after one week of the disease's infection, 5 died within two weeks, and two patients died on day 30 following the disease's onset [4].

A recent Nipah virus spillover appeared in Kerala, in 2018. It began with a man in Kozhikode who died from the virus with documentation that he suffered from high-grade fever, vomiting and altered sensorium before death [8, 21]. During this outbreak, nosocomial transmission led to a total of 23 infections, with 21 deaths and a high fatality rate of 91% [8]. The outbreak was likely linked to exposure to an infected bat during its breeding season with an incubation period of 6 to 14 days in the patients. This outbreak demonstrated fewer clinical features relating to respiratory symptoms than the cases in 2001 in both Siliguri and Bangladesh [21].

4. Impacts of Agricultural Expansion on Nipah Virus Ecology

Agricultural expansion is driven by a variety of factors that influence methods of cultivation and supply of food. Population and economic growth, technological advancements, facilitated transportation, urbanisation, and environmental conditions are all important factors that change farming methods to meet growing food demands [1]. Increasing the yields and efficiency of crops improves markets of agricultural products more successfully due to developed access to both domestic and foreign markets [15]. By examining the previous cases, the impacts can be summarised into bats' habitat modification, changing wildlife interactions, and intensified farming conditions.

Drought as a result of habitat modification, has been suggested as one of the factors affecting the Malaysia 1998-1999 and Kerala 2018 cases [8, 14]. Deforestation and drought worked together in reducing the availability of fruits and roost trees favoured by the fruit bats. Loss of a single roost tree, especially one with preferred characteristics such as a tall canopy and large trunk, could drastically affect local bat populations without significantly changing overall deforestation rates [6]. Therefore, the fruit bats were forced to forage in places near farms and gardens, contributing to the spillover events of the Nipah virus. This migration of bats may influence Nipah virus transmission, as those infected bats could

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initiate outbreaks elsewhere. Cutting roost trees should be discouraged to prevent spillover and support bat conservation [6].

Wildlife interactions were altered when fruit trees were being planted very near the pig farms. The farmers planted orchards in order to improve crop yield and food production for higher income. However, this action attracted Pteropus fruit bats over food foraging and contaminated the environment with the virus, leading to the epidemic of Nipah virus in Malaysia [6, 7].

The outbreak in Siliguri, India, numerically suggested the idea that it was due to the lack of routine prophylaxis in local hospitals with both health professionals and patients [4]. Meaning that the transmission was not directly connected to agricultural expansion. However, West Bengal and Bangladesh share similar environmental conditions due to their geographical proximity and location within the Bengal Basin [1, 22]. Thus, we suspect that the outbreak of the Nipah virus in Siliguri was a result of fruit bats migrating to Siliguri from Bangladesh as a result of changes brought about by agricultural growth, including the reduction or loss of their natural habitat.

Meanwhile, the intensified farming conditions were also a crucial consequence. Intensification of livestock farming is the action of maximising animal production through the use of land, nutrition, and water resources. This often involves methods such as higher-density animal housing and the use of antibiotics and hormones to boost growth rates [23]. Intensification can also bring about a number of problems, for example, an increase in animal-to-human disease transmission, and a higher chance of zoonotic epidemics. The close proximity of animals in intensive farming practices can facilitate the spread of Nipah virus pathogens [6]. Additionally, the stresses on livestock from overcrowding can inadequate nutrition can weaken their immune systems, making them more vulnerable to infections.

5. Conclusion

In conclusion, the relationship between agricultural expansion and Nipah virus ecology emphasises the need for understanding how land-use changes impact zoonotic disease transmission. As agricultural methods develop in ecosystems, the possibility of spillover events from wildlife to livestock and then to people rises tremendously. Habitat modification, changing wildlife interactions, and intensified farming conditions contributed to the transmission of the Nipah virus.

To cope with this complicated issue, collaborations between ecologists, public health authorities, veterinarians, and agricultural experts are essential in creating strategies considering biodiversity, disease monitoring, and methods for sustainable agriculture. By prioritising the health of both our communities and the environment, we can ensure a more stable and safe future for agriculture and public health.

References

[1] Kulkarni, D. D., Tosh, C., Venkatesh, G., & Senthil Kumar, D. (2013). Nipah virus infection: current scenario. Indian journal of virology : an official organ of Indian Virological Society, 24(3), 398–408. https://doi.org/10.1007/s13337-013-0171-y

[2] Centers for Disease Control and Prevention (CDC). Outbreak of Hendra-like virus--Malaysia and Singapore, 1998-1999. MMWR Morb Mortal Wkly Rep. 1999 Apr 9;48(13):265-9. Erratum in: MMWR Morb Mortal Wkly Rep 1999 Apr 30;48(16):339. PMID: 10227800.

[3] Banerjee, S., Gupta, N., Kodan, P., Mittal, A., Ray, Y., Nischal, N., Soneja, M., Biswas, A., & Wig, N. (2019). Nipah virus disease: A rare and intractable disease. Intractable & rare diseases research, 8(1), 1–8. https://doi.org/10.5582/irdr.2018.01130

[4] Chadha, M. S., Comer, J. A., Lowe, L., Rota, P. A., Rollin, P. E., Bellini, W. J., Ksiazek, T. G., & Mishra, A. (2006). Nipah virus-associated encephalitis outbreak, Siliguri, India. Emerging infectious diseases, 12(2), 235–240. https://doi.org/10.3201/eid1202.051247

[5] 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., & Working Group on Land Use Change and Disease Emergence (2004). Unhealthy landscapes: Policy recommendations

DOI: 10.54254/2753-8818/65/2024.LA18087

on land use change and infectious disease emergence. Environmental health perspectives, 112(10), 1092–1098. https://doi.org/10.1289/ehp.6877

[6] McKee, C. D., Islam, A., Rahman, M. Z., Khan, S. U., Rahman, M., Satter, S. M., Islam, A., Yinda, C. K., Epstein, J. H., Daszak, P., Munster, V. J., Hudson, P. J., Plowright, R. K., Luby, S. P., & Gurley, E. S. (2022). Nipah Virus Detection at Bat Roosts after Spillover Events, Bangladesh, 2012-2019. Emerging infectious diseases, 28(7), 1384–1392. https://doi.org/10.3201/eid2807.212614

[7] Epstein, J. H., Field, H. E., Luby, S., Pulliam, J. R., & Daszak, P. (2006). Nipah virus: impact, origins, and causes of emergence. Current infectious disease reports, 8(1), 59–65. https://doi.org/10.1007/s11908-006-0036-2

[8] Soman Pillai, V., Krishna, G., & Valiya Veettil, M. (2020). Nipah Virus: Past Outbreaks and Future Containment. Viruses, 12(4), 465. https://doi.org/10.3390/v12040465

[9] Pulliam, J. R., Epstein, J. H., Dushoff, J., Rahman, S. A., Bunning, M., Jamaluddin, A. A., Hyatt, A. D., Field, H. E., Dobson, A. P., Daszak, P., & Henipavirus Ecology Research Group (HERG) (2012). Agricultural intensification, priming for persistence and the emergence of Nipah virus: a lethal bat-borne zoonosis. Journal of the Royal Society, Interface, 9(66), 89–101. https://doi.org/10.1098/rsif.2011.0223

[10] Singh, R. K., Dhama, K., Chakraborty, S., Tiwari, R., Natesan, S., Khandia, R., Munjal, A., Vora, K. S., Latheef, S. K., Karthik, K., Singh Malik, Y., Singh, R., Chaicumpa, W., & Mourya, D. T. (2019). Nipah virus: epidemiology, pathology, immunobiology and advances in diagnosis, vaccine designing and control strategies - a comprehensive review. The veterinary quarterly, 39(1), 26–55. https://doi.org/10.1080/01652176.2019.1580827

[11] Goh, K. J., Tan, C. T., Chew, N. K., Tan, P. S., Kamarulzaman, A., Sarji, S. A., Wong, K. T., Abdullah, B. J., Chua, K. B., & Lam, S. K. (2000). Clinical features of Nipah virus encephalitis among pig farmers in Malaysia. The New England journal of medicine, 342(17), 1229–1235. https://doi.org/10.1056/NEJM200004273421701

[12] Chua KB. Epidemiology, surveillance and control of Nipah virus infections in Malaysia. Malays J Pathol. 2010 Dec;32(2):69-73. PMID: 21329176.

[13] Aditi, & Shariff, M. (2019). Nipah virus infection: A review. Epidemiology and infection, 147, e95. https://doi.org/10.1017/S0950268819000086

[14] Chua, K. B., Chua, B. H., & Wang, C. W. (2002). Anthropogenic deforestation, El Niño and the emergence of Nipah virus in Malaysia. The Malaysian journal of pathology, 24(1), 15–21.

[15] Mohd Nor, M. N., Gan, C. H., & Ong, B. L. (2000). Nipah virus infection of pigs in peninsular Malaysia. Revue scientifique et technique (International Office of Epizootics), 19(1), 160–165. https://doi.org/10.20506/rst.19.1.1202

[16] Chua, K. B., Lam, S. K., Goh, K. J., Hooi, P. S., Ksiazek, T. G., Kamarulzaman, A., Olson, J., & Tan, C. T. (2001). The presence of Nipah virus in respiratory secretions and urine of patients during an outbreak of Nipah virus encephalitis in Malaysia. The Journal of infection, 42(1), 40–43. https://doi.org/10.1053/jinf.2000.0782

[17] Parashar, U. D., Sunn, L. M., Ong, F., Mounts, A. W., Arif, M. T., Ksiazek, T. G., Kamaluddin, M. A., Mustafa, A. N., Kaur, H., Ding, L. M., Othman, G., Radzi, H. M., Kitsutani, P. T., Stockton, P. C., Arokiasamy, J., Gary, H. E., Jr, & Anderson, L. J. (2000). Case-control study of risk factors for human infection with a new zoonotic paramyxovirus, Nipah virus, during a 1998-1999 outbreak of severe encephalitis in Malaysia. The Journal of infectious diseases, 181(5), 1755–1759. https://doi.org/10.1086/315457

[18] Hsu, V. P., Hossain, M. J., Parashar, U. D., Ali, M. M., Ksiazek, T. G., Kuzmin, I., Niezgoda, M. , Rupprecht, C., Bresee, J., & Breiman, R. F. (2004). Nipah virus encephalitis reemergence, Bangladesh. Emerging infectious diseases, 10(12), 2082–2087. https://doi.org/10.3201/eid1012.040701

[19] Luby, S. P., Rahman, M., Hossain, M. J., Blum, L. S., Husain, M. M., Gurley, E., Khan, R., Ahmed, B. N., Rahman, S., Nahar, N., Kenah, E., Comer, J. A., & Ksiazek, T. G. (2006).

DOI: 10.54254/2753-8818/65/2024.LA18087

Foodborne transmission of Nipah virus, Bangladesh. Emerging infectious diseases, 12(12), 1888–1894. https://doi.org/10.3201/eid1212.060732

[20] Rahman MA, Hossain MJ, Sultana S, Homaira N, Khan SU, Rahman M, Gurley ES, Rollin PE, Lo MK, Comer JA, Lowe L, Rota PA, Ksiazek TG, Kenah E, Sharker Y, Luby SP. Date palm sap linked to Nipah virus outbreak in Bangladesh, 2008. Vector Borne Zoonotic Dis. 2012 Jan;12(1):65-72. doi: 10.1089/vbz.2011.0656. Epub 2011 Sep 16. PMID: 21923274.

[21] Thulaseedaran, N. K., Kumar, K. G. S., Kumar, J., Geetha, P., Jayachandran, N. V., Kamalasanan, C. G., Mathew, S., & Pv, S. (2018). A Case Series on the Recent Nipah Epidemic in Kerala. The Journal of the Association of Physicians of India, 66(10), 63–67.

[22] Mandal, T., Das, J., Rahman, A. T. M. S., & Saha, P. (1970, January 1). Rainfall insight in Bangladesh and India: Climate change and environmental perspective. SpringerLink. https://link.springer.com/chapter/10.1007/978-3-030-49115-4_3

[23] W. Gilbert a, a, b, & AbstractMajor shifts in how animals are bred. (2020, December 15). Review: Mitigating the risks posed by intensification in livestock production: The examples of antimicrobial resistance and Zoonoses. animal. https://www.sciencedirect.com/science/article/pii/S1751731120301257