Review Article

Landscape of zoonoses clusters in Bangladesh from 2001 to 2016: Impact to National Health

Abstract

Spatiotemporal distributions and driving factors of human diseases remain obscure in Bangladesh despite its various zoonotic diseases. Using the National Health Surveillance Data for 2000-2016, we conducted a retrospective epidemiological study of the viral dengue fever (DF), Nipah virus encephalitis (NiVE), rabies, zika, protozoan malaria and bacterial anthrax in Bangladesh, along with their risk factors, transmission mode and prevailing treatment. Dengue morbidity/mortality was 375-6132 cases and 0-2.05%, respectively. Major hotspots included urban Dhaka, Khulna and Chittagong. All four causative virus serotypes were reported. Nipah morbidity/mortality was 4-44 cases and 25-92%, respectively. The highest burden was in the northwestern and central districts, with 31 geographical clusters. Zika, was and is still an emerging disease with few reported cases. However, Zika has the potential to cause a public health burden. Rabies cases from dog bites spurred in Dhaka and the surrounding regions. The morbidity/mortality for rabies was 0-100,000 cases and 0-3.61%, respectively. Anthrax morbidity/mortality was 0-607 cases and 0-0.0164%, respectively. Disease prevalence was in Sirajganj and neighboring regions. Most cases were attributed to butchers handling infected cattle-meat. Environmental conditions have optimized the growth of the causative bacteria *Bacillus antharcis*. Malaria morbidity/mortality was 3864-84690 and 0.03-0.54%, respectively. The protozoa *P. falcifarum* was responsible for 28.6- 95.2% of the cases. Malaria is hyper-endemic in the Khagrachari, Bandarban and Rangamati districts. The introduction of advanced diagnostic, preventative and treatments against malaria, initiated in the early 2000's, have been

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successful. Although disease endemocities for malaria, dangue and zika have not been effectively captured by the National Surveillance, key risk factors for these diseases include mosquito outbreaks. This report highlights the need continued zoonotic disease surveillance to control the regional disease burden.

Key words: Bangladesh, Zoonotic diseases, Nipha, dengue, malaria (write in alphabetical orders)

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Introduction

There are approximately 1,415 pathogens that are morbific to humans, of which, approximately 61% are zoonotic (Samad, 2013). Zoonoses constitute 58% of human diseases and 60% of emerging diseases (Woolhouse and Gowtage-Sequeria, 2005; Hugh-Jones, Hubert and Hagstad, 2008). The zoonotic pathogens prevailing throughout Bangladesh are an enormous burden to the country's public health and there are several transmission pathways that promote morbidities and comorbidities (Ferdous *et al.*, 2004; Loh *et al.*, 2015). In comparison to countries of Latin America and Africa vector borne pathogens cause relatively few public health problems in Bangladesh and other parts of Asia (Conlan *et al.*, 2011; *World malaria report*, 2016). However, Bangladesh is undergoing changes with respect to climate change, environmental degradation, deforestation, socioeconomic development and the industrialization of livestock production (Hasnat *et al.*, 2018). These changes have the potential to influence the distribution, prevalence and severity of zoonotic diseases. The lack of active surveillance and information further worsens this situation.

Thus, zoonoses prevention and control remains a hot topic of discussion as a field that needs improvement and efficient administration in Bangladesh. This review provides updates of

epidemiological aspects of the diseases NiV encephalitis, rabies, zika, dengue fever, malaria and anthrax and briefly, discusses the implications for the design and implementation of prevention and control programs and research initiatives.

Methodology:

Pertinent Information was obtained from published articles and reports. Electronic databases (PubMed, IEDCR website and Google Scholar) were searched using the terms: “Nipah encephalitis”, “Rabies”, “Dengue fever”, “Zika”, “Malaria” combined with “Bangladesh”. The coordinates (longitude and latitude) of all outbreak districts were retrieved using Google map software. GPS points were then uploaded to a Fox Pro database system. With the help of this database and Arc GIS 9.2 software zoonotic diseases maps of Bangladesh was constructed for each disease.

Results and Discussion:

Dengue Fever, also known as Breakbone fever

Owing to its geographic position and climatic conditions, Bangladesh has become an ideal breeding ground for dengue transmission (Mutsuddy *et al.*, 2019). Secondary infections of the same or different arbovirus result in a severe form of this illness called Dengue Hemorrhagic Fever (DHF) (Rahman *et al.*, 2002).

Epidemiology:

Bangladesh recorded a total 41,205 human DF cases from 29 of the 65 districts between 2001-2016 (Figure 1A, 1B). The case numbers heightened to an astounding 6132 during the 2002

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epidemic. This was accompanied by a case fatality rate (CFR) of 1%. The lowest number of recorded cases, 375, occurred in 2014 and no casualties were recorded. Dengue was first documented in Bangladesh (Dhaka city) in 1964 (Sharmin *et al.*, 2015). A small number of cases were reported from 1977 to 1978 and from 1996 to 1997 (Yunus *et al.*, 2001; Hossain *et al.*, 2003). As evidenced by the numerous counts of serologically determined primary and secondary infections, the dengue virus serotypes have been actively co-circulating in Bangladesh since 1964 (Mannan, Chowdhuri and Banu, 1999; Control and Care, 2000; Hossain *et al.*, 2003). In 2000, the first dengue outbreak occurred in the major cities of Dhaka, Khulna, Chittagong and 17 other towns. Dhaka had the highest number of reported human cases (4385 out of a total of 5551), which constituted of 4385 DF patients (98.9%) and 1166 DHF patients (21.1%), with 93 fatalities (CFR-1.7 %). Serological assays from the 2000 outbreak confirmed that DEN-3 was the dominant serotype (Yunus *et al.*, 2001). Bangladesh experienced the deadliest epidemic in 2002 with 6132 reported human cases and a CFR of 1% (Sharmin, 2017). As a result, improved reporting from Dhaka was implemented. Results of a hospital-based study on dengue prevalence in febrile patients, conducted from 2008-2009, revealed an almost equal number of patients from both urban (city and district residents) and rural areas (sub-district residents) that were seropositive for DENV antibodies (Faruque *et al.*, 2012).

In 2012, the first population-based cross-sectional seroprevalence study conducted in 12 out of 90 wards in Dhaka, revealed anti-dengue antibodies by IgM and IgG capture ELISA in 2.0% and 80.0% of participants, respectively (Health and Science Bulletin, 2014). The number of positive cases was 923 out of 1125 participants. This relevant information was not captured by the National Surveillance. Additionally, during the first population-based nationwide seroprevalence study in 2014, IgG ELISA was used to identify 703 positive cases out of 2905 participants

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(24%). Interestingly, a hospital-based surveillance only reported 367 positive cases during this time. Since dengue is asymptomatic in children, the positive cases reflect a mainly adult (≥ 18 years of age) population (Kishor *et al.*, 2017). Most cases of dengue were reported in June and a decrease in reported cases occurred in November. Seasonality in dengue morbidities and comorbidities vary from year to year. This is dependent on the timing and magnitude of seasonal peaks, which are influenced by climate and the concomitant effects on *Aedes* population size, as well as changes in DENV activity. Table 1 pinpoints more information of this disease.

Nipah Virus Encephalitis

NiVE is an emerging infectious zoonotic disease (EID) (Goh *et al.*, 2002; Chua, 2003) in Bangladesh that has caused sporadic outbreak events dating back as far as 2001 (Hsu *et al.*, 2004; Luby *et al.*, 2009).

Epidemiology

The Nipah virus strain, NiV_B is the etiological agent responsible for numerous seasonal outbreaks in Bangladesh from 2001 to 2015. These local outbreaks were prevalent in the Northwestern and Central regions (Figure 1C) and occurred mainly in the winter months between December through May. A total of 13 outbreaks occurred from 2001 to 2015 (Islam and Rahman, 2016; Siddique *et al.*, 2016). The CFR of NiVE ranged from 40% to 90%; although CFR was as high as 100% in some outbreaks outside the country during this time. The morbidity and mortality of NiVE infection is shown in Figure 1D. Other aspects of the disease have been highlighted in Table 1. Of note, the Meherpur outbreak begun with a 33-year-old male index

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patient who presented with flu like symptoms on April 20, 2001. A cluster of 5 cases occurred in his household. An additional eight individual households were affected, and all the case patients were either blood relatives or associates of the index patient. The outbreak ended with a female victim, aged 60 years, who was a neighbor of the index case. This data is enough to warrant the potential risk of a NiVE contagion. In the 2003 Naogaon outbreak, the index patient was a 12-year-old male, who presented with symptoms on January 11th and the final recorded case was a 12-year old female, who presented with symptoms on January 28th. Another cluster of five cases occurred in the same household. Eight additional households were affected; however, no clustering in the community was recorded. Importantly, members of each of these households were not related to those of other affected households (Hsu *et al.*, 2004).

During the Rajbari outbreak the following year (2004), three geographic clusters were recorded in Goalando. All household members of the two clusters reported climbing trees prior to developing symptoms. However, no evidence of Nipah transmission through direct contact amongst the family members was recorded. Another contemporaneous Faridpur outbreak was perhaps the deadliest Nipah encephalitis outbreak in the epidemiological history of Bangladesh. This outbreak lasted for two months across seven villages; 92% of patients were infected through secondary and tertiary person-to-person Nipah transmission. A total of five geographic clusters were identified. The most significant contagion began when Nipah encephalitis befell a household resulting in a cluster of five cases. One patient sought care from a popular local sage, or religious leader. After-which, the sage was coined the “super spreader” of the outbreak. During his illness, 36 patients had contact with him including 8 of his 10 household members. One of the diseased patients in turn, infected three other people. During this outbreak, most of the patients died (Rahman, 2011).

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In Tangail, a cluster of three cases in a single household was detected in 2005. All afflicted cases lived within 8 km of each other but were not relatives. Drinking raw date palm sap was first implicated in NiVE transmission during this outbreak (Rahman, 2011).

The first case of the 2007 Thakurgaon outbreak was an adult male with symptom onset on January 21th. He was responsible for infecting 14 other individuals who had physical contact with him, including three of his household members. The first victim of Khustia outbreak (2007) was a 55-year old female who developed the disease on March 17th and infected five caregivers who had physical contact with the patient. Two other cases were reported from individuals who fell ill while attending a religious gathering in proximity to the index case, for a few hours, but had no direct contact with the patient (Rahman, 2011).

In 2008, an outbreak spanned across two communities of Manikganj and Rajbari, 44 km apart and separated by the Padma river. These outbreak areas were within the foraging ranges of the endemic *Pteropus* bat (Kunz and Jones 2000). The bat population was attributed with contamination of the raw date palm sap collected there. Use of the contaminated sap associated with Nipah infection, was contained to these areas. The Rajbari cluster consisted of six cases from the same household who shared purchased raw date palm sap. Subsequently, all of them had contracted the virus (Rahman *et al.*, 2011).

From December 2009 to March 2010, another Nipah outbreak in the Faridpur and Gopalganj districts caused three geographic clusters. The first cluster consisted of two cases. Both patients died after presenting with Nipah encephalitis-like symptoms. However, serological assays showed that both were negative for NiVE. The second cluster also consisted of two cases who (that added) showed similar symptoms, but no epidemiological link between them was discerned. The third reported cluster involved as many as eight patients from the Bhanga subdistrict. The

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index case was a 45-year old male who, soon after being admitted to the district hospital, died. Ten subsequent morbidities were reported. The household of the male index case from the second report was situated under a bat roost. He and his wife shared raw date palm sap and illness befell both, although the wife survived. Three additional isolated cases involved a pediatrician who was treating two female patients, without utilizing personal protective equipment. This was the first reported hospital acquired infection of NiVE in Bangladesh (Sazzad, 2010).

Another outbreak of wider geographic epidemicity, spanned from December 2010 to March 2011. This outbreak reported four clusters involving 37 cases. A large cluster of 22 cases occurred in Lalmonirhat. The remaining three clusters occurred in the districts of Rangpurwith (space) (8 cases), Dinajpur (5 cases) and, Rajbari (2 cases). The remaining six cases were reported as isolated. Three of the eight cases in the Rangpur cluster were attributed to the consumption of fermented date palm sap (tari) prior to the onset of symptoms. Of the five cases in the Dinajpur cluster, two patients had consumed raw date palm sap prior to illness. Two secondary cases developed after encountering these probable cases, the third developed after exposure to one of the secondary patients. An isolated case from Comilla was identified in a patient with a history of drinking raw date sap. Serum showed that all patients were positive for IgM antibodies against NiV (Chakraborty *et al.*, 2016). Little is known about the outbreaks following 2011 due to limited National Surveillance.

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Rabies

Rabies is a zoonotic neurotropic disease that is of public health significance in Bangladesh. Over 90% of human rabies infections are due to bites from infected dogs (Rahman *et al.*, 2007).

Epidemiology

Rabies virus (RABV) of the *Lyssavirus* genus is the etiologic agent of rabies in the region (*Frequently asked questions about rabies for the General Public*, 2018). Its presence has demeaned Bangladesh as the third largest rabies burden country in the world. Approximately 200,000 animal bite cases and over 2,000 human rabies caused deaths were reported every year (Ghosh *et al.*, 2016). The disease was first recorded in 1999 during a hospital-based survey at the Infectious Disease Hospital (IDH) in Dhaka. Many of the cases were from rural and marginalized urban populations. Children and young adults were the primary victims (Rahman *et al.*, 2007). The morbidity and mortality of rabies infection is given in Figure 1F. Until 2008, casualties due to rabies infection in hospitals was not recorded. In addition, many surveys did not categorize injuries of rabies cases. The retrospective study of the virus's dynamics pinpoints to the increased spread of the rabies virus over time. Initially, most of the reported patients were from Dhaka and the surrounding six districts of: Gazipur, Narsingdi, Narayanganj, Comilla, Munshiganj and Manikganj. Surveys taken in the succeeding years depicted a rise in cases nationwide (Figure 1E). An additional forty-eight districts were affected alongside the aforementioned ones including: Faridpur, Gopalganj, Madaripur, Rajbari, Shariatpur Brahmanbaria, Chandpur, Comilla, Feni, Laksmipur, Noakhali, Jamalpur, Kishorganj, Mymensingh, Netrokona, Sherpur, Tangail, Barisal, Bhola, Borguna, Jhalakati, Patuakhali, Pirojpur, Bogra, Pabna, Panchagar, Rajshahi, Sirajganj, Naogaon, Nator, Chuadanga, Jhenaidah, Jessore, Khulna, Kushtia, Narail, Habiganj, Moulovibazar Sunamganj, Sylhet, Dinajpur,

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Gaibandha, Jaipurhat, Kurigram and Nilphamari. In addition to hospital reported cases, the first Nationwide (space) community-based survey across 30 upazillas from all seven divisions was conducted in 2006. This (These is added) revealed approximately 8,000 cases with 68 deaths (CFR-0.88%) (Hossain *et al.*, 2012). Rabid animal bites are prevalent year-round. However, maximal infection rates occurred in the months of January, April and December. Rates are reported to decline in the month of June (Hossain *et al.*, 2011). There is no correlation between rabies victims and any other meteorological factors. RABV is unique because it circulates in two epidemiological cycles called the urban and sylvatic cycle, which include livestock, pets, stray mammals and wild mammals. Canine rabies is most the prevalent and caused mostly by dogs and cats while other animals like fox, monkey, jackal, mongoose and bats occasionally transmit rabies (Singh *et al.*, 2017). Further information on this disease is provided in table 1.

Zika fever or Zika

Zika fever is an emerging newfound disease known for its notoriety of 'explosive' pandemic capacity (Lucey and Gostin, 2016).

Epidemiology

Vectored by the aggressive *Aedes* mosquitoes, the Zika virus is an RNA flavivirus that is closely related to dengue and yellow flavivirus and it produces an infectious disease known as Zika fever or Zika (Valley, 2017). Zika was first isolated from Rhesus monkeys in Uganda in 1947. Its first outbreak occurred in 2007 in the Federated States of Micronesia and the virus spread across other parts of Oceania (Posen *et al.*, 2016). In 2015 the Pan American Health Organization

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(PAHO) declared Zika a public health emergency following the first viral infection in Brazil (Lowe *et al.*, 2018). In 2016, the outbreaks became pandemic, extending to 20 regions in the Americas, Africa, Asia, and the Pacific (Lucey and Gostin O., 2016; Talero-Gutiérrez *et al.*, 2018). Bangladesh, like its neighbor's, confirmed the first case of Zika virus in a previously obtained blood sample from a 65-year-old man on March 22, 2016, who resided in the southern port city of Chittagong (Mourya *et al.*, 2016; Muraduzzaman *et al.*, 2017). Little is known of the virus and the disease. This elderly patient is the only newfound case in Bangladesh. Other aspects of this disease are discussed in Table 1.

Malaria

Bangladesh, like its neighboring countries, has had its fair share of reported vector-borne protozoan diseases. Malaria is one of the most prominent vector-borne zoonotic protozoan and tropical diseases. Its occurrence prevailed in the 1980s after emergence in Bangladesh (Haque *et al.*, 2009; Conlan *et al.*, 2011; Kumar *et al.*, 2015).

Epidemiology

Malaria is hyperendemic in 13 of the 65 districts in Bangladesh (Figure A1of 2). The eight Northeastern districts, which share a common border with India, include Sherpur, Mymensingh, Netrokona, Kurigram, Sylhet, Hobiganj, Sunamganj and Moulovibazar. Three of five districts in the Southeast of Bangladesh, which share a common border with India and Myanmar, include: Khagrachari, Rangamati and Bandarban. The other two districts are Chittagong and Cox's Bazar. India and Myanmar accounted for 90% and 1% of estimated malarial morbidities in WHO Southeast Asian region, respectively (*World Malaria Report*, 2017). Thus, the spread of this

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disease into the bordering areas is inevitable. The general population, however, is not prone to the disease. Malaria in Bangladesh is primarily caused by two protozoan parasites, *Plasmodium falciparum* and *Plasmodium vivax*. The innate practice of consuming human blood place *Anopheles* mosquitoes at risk of acquiring and vectoring these pathogens into humans, their primary hosts. *Plasmodium falciparum* predominates the malarial morbidity status with estimates range between 71 to 95%, illustrated in Figure 2B (Alam *et al.*, 2010; *World Malaria Report*, 2017). Over the past sixteen years, an increase in the trend of malaria morbidities caused by *P. falciparum* has been reported. This is due to more people living in or near forest thickets, especially in Chittagong Hill Tracts (CHT). Other clinically important species include *P. vivax*, *P. malariae* and related sibling species of *P. ovale*. *P. vivax* is now reported to cause less than 10% of the malarial morbidities; the trend is showing a growing increase. Of thirteen districts, *P. falciparum* was found in eleven and *P. vivax* was found in ten. Mixed infections due to these two species were found in all thirteen districts. Malaria prevalence was significantly higher in children compared to adults. The overall weighted prevalence rate was high in the Khagrachari, Bandarban and Rangamati districts, collectively called the CHT area, reported ranges were from 3.10 to 3.97%. Bandarban exhibited the highest prevalence rate (36%). The CHT area is hyperendemic to malaria with a prevalence of more than 11% (Figure A2) (Hussain *et al.*, 2003; Haque *et al.*, 2011; Maude *et al.*, 2012). With its long-time prevalence and potential to infect over 17 million people, the route of transmission of these parasites is still poorly understood. Figure 2C shows annual malarial cases in Bangladesh, depicting a steady rise from 2000 to 2008 (*World Malaria Report*, 2017). This increase may be attributed to the ban of dichlorodiphenyltrichloroethane (DDT) in 1985, leading to an interruption of the malaria eradication programs, coupled with a large population movement during the 1971 War of

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Independence. Outbreak numbers also vary between years due to climate change (Islam, Bonovas and Nikolopoulos, 2013). Mortality peaked in 2006 and over 95% of the cases were reported from the thirteen districts. Since these thirteen districts have little or no accessibility due to the hilly terrain, insufficient surveillance information systems were unable to effectively capture the true number of malaria cases by the Ministry of Health, Government of Bangladesh (Haque *et al.*, 2009). All age groups are afflicted with most victims being young adults of fifteen years or over. The decrease in malaria prevalence from 2008 onwards was associated with increased insecticide-treated net coverage and increased drug treatment coverage (Figures 2D1 and 2D2) (Islam, Bonovas and Nikolopoulos, 2013). Other aspects of this disease are shown in Table 1.

Anthrax

In Bangladesh only cutaneous and gastrointestinal anthrax cases have been reported as of date

Epidemiology:

The causative agent of this serious communicable disease is the bacterium *Bacillus anthracis*. Although anthrax predates the 2000s, its infectious nature has only been brought to light since 2009 (Samad and Hoque, 1986; World Health organization, 2008). Figure 3B shows the morbidity and mortality of anthrax infections. Community-based studies conducted between 2009-2010 in the Anthrax Belt (AB), identified twenty-nine human anthrax outbreaks. The first survey that spanned from 2009 to 2010 identified three outbreaks in 2009 and eleven outbreaks in 2010. A total of 273 human cutaneous anthrax cases were reported. Of these patients, 25 were suspected of gastrointestinal anthrax based on symptoms. Patients from all age groups especially young adults and adults, comprised about 20% of the total patients that were infected

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(Chakraborty *et al.*, 2012). A hospital-based survey conducted in Rajshahi outlined a clinic-demographic profile of patients suffering from cutaneous anthrax with a reported age range of 3 to 40 years, most were of poor socio-economic status, poorly educated and had little knowledge of the disease. Most victims contracted the disease because they were involved in butchery (64%) and had direct dermal contact (approximately 50%) with infected cattle meat (Siddiqui *et al.*, 2012). This led to further monitoring of the spread of anthrax in the following years. Official data released by Institute of Epidemiology Disease Control and Research (IEDCR), reported cases from the flood prone Northern districts of Sirajganj and the neighboring districts of Pabna, Tangail and Rajshahi. The main cattle farms are situated in this region (AB). Other districts had several case reports including Manikganj, Khustia, Meherpur, Narayangonj, Laxmipur, Bogra, Chapai Nawabganj, Chuadhanga and Chittagong (Figure 3A) (*Anthrax outbreak*, 2018).

Conclusion:

The occurrence of viral, bacterial and parasitic zoonoses circulating in Bangladesh are a major burden to public health and create an economic burden to the impacted areas. The magnitude and scope of this burden varies for each of the pathogens discussed. Climate changes have the potential to increase the abundance and distribution of pathogens, thereby placing far more people at risk of infection. Vector borne zoonotic pathogens merit advanced surveillance schemes to include, longitudinal clinical surveillance that utilizes both passive and active data collection processes and cross-sectional parasite screening (only in case of malaria). National Surveillance for most diseases, is limited and primarily only hospital, not community based. It is not surprising that the cases of malaria, dengue, rabies, and anthrax are under-reported. Disease prevention and treatments are well administered for only malaria, which is endemic to the region. These include the usage of long-lasting insecticide treated nets to ward off mosquitoes, larval

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control and different artesian based compound therapies. Deployment of advanced diagnostic methods to detect the spread of malaria, such as RDTs, began in 2013. However, for zoonotic disease, surveillance is restricted to time consuming microscopy and antibody blood tests. For diseases such as NiVE, DF, and zika, supportive care is the main and sometimes the only mode of treatment. Zika is a novel emerging disease in Bangladesh and could possibly lead to outbreaks in the future as feared by WHO. To resolve these problems several steps, need to be taken by country's own governing body. Both human and animal health systems need to exert collaborative, and sometimes international, cross-sectional efforts that also consider the complexities of the ecosystems where humans and animals co-exist. Active collaboration between international companies, GoB (Government of Bangladesh) and NGO partners in Bangladesh are important to assess local, regional and global societal burdens and the cost-effectiveness of intervention strategies. Climate and weather data with high spatial resolution can help predict spatial and temporal patterns of vector dynamics and can aid planning of regional campaigns. Meteorological studies have been used to identify social and economical predictors of malaria risk assessments in other regions (Solano-Villarreal *et al*., 2019), similar strategies may benefit Bangladesh. Improving collaboration by strengthening mechanisms for information exchange across relevant sectors and programs in countries, between health and agriculture sectors and raising awareness among stakeholder communities through campaigns, commercials and postering can improve the disease burden considerably.

Reduction of disease prevalence and an increased level of awareness of zoonotic diseases has a positive health impact. Efforts should be made to continue ongoing disease control activities, with the aim of rapid disease elimination in endemic areas. This review should instigate public

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health stakeholders to place emphasizes on understanding the epidemiology of the discussed zoonotic diseases, and for taking preventive actions in Bangladesh, as well as in Southeast Asia.

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Figure Legends:

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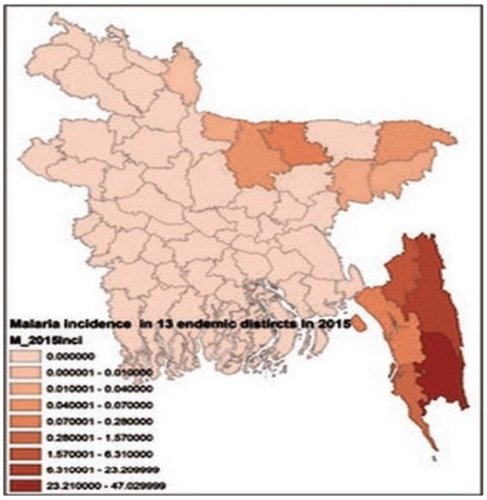

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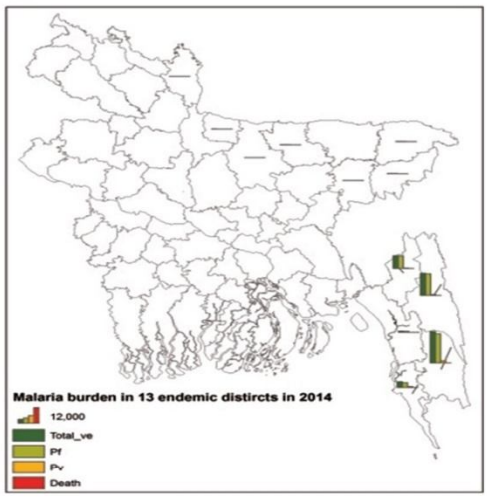

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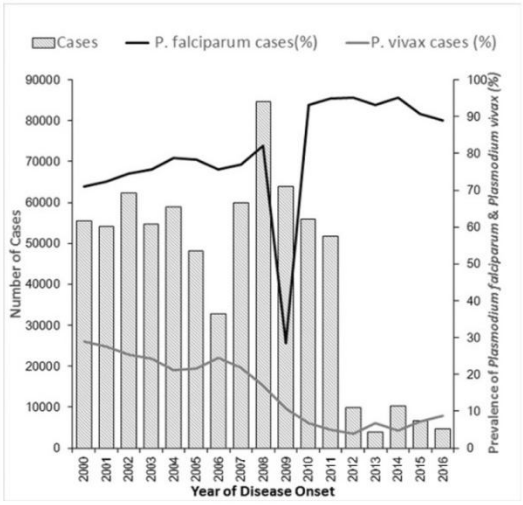

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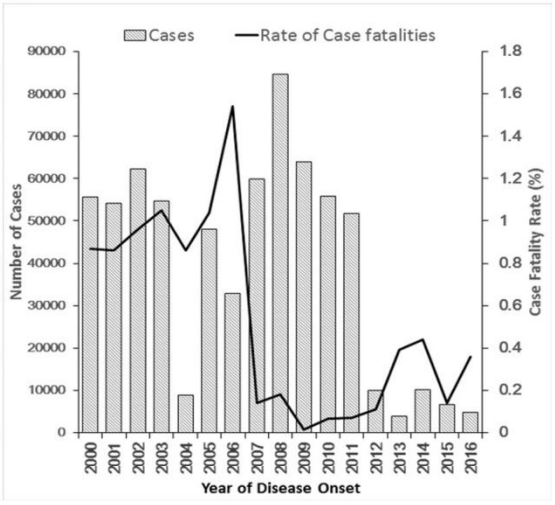
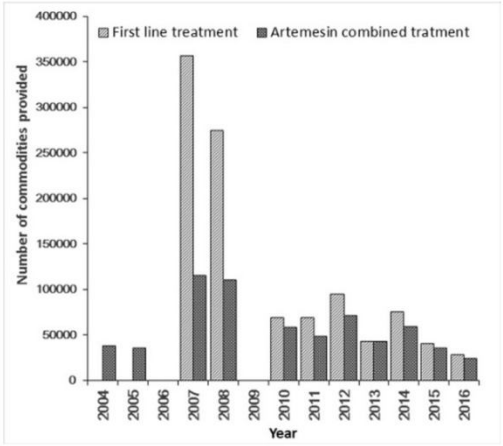


D1.



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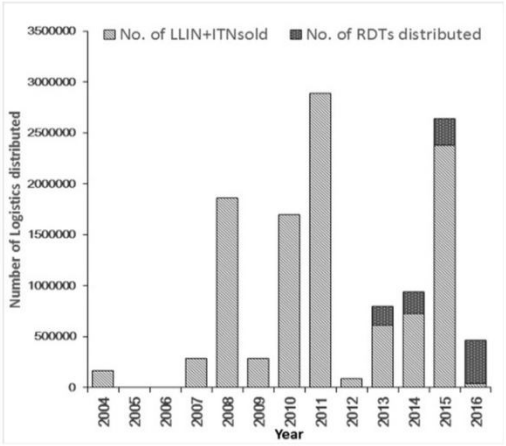

Figure 1. Epidemiological overview of malaria in Bangladesh. Map of Bangladesh illustrates district distribution of the estimated number of diagnosed cases of malaria reported in humans, 2000-2016 (A_{1-2}). Malaria is hyperendemic within the Chittagong district and parts of the Sylhet district. Temporal distribution of malaria cases and mortalities in Bangladesh during 2000-2016 (B). The morbidities and mortalities fluctuate and share no correlation. Events in the recent years indicate that more virulent strains are killing victims as the case fatality rate curve increases. Prevalence of *P. falciparum* and *P. vivax* and malaria cases with respect to year (C). Distribution of treatment and logistics with respect to year (D_{1-2}). Donation of long-lasting insecticidal nets (LLIN) peaked during 2011 while distribution of rapid diagnostic tests (RDT) peaked in 2016.

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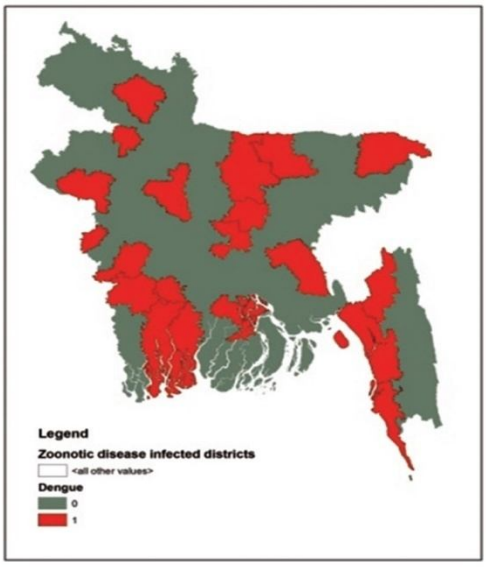
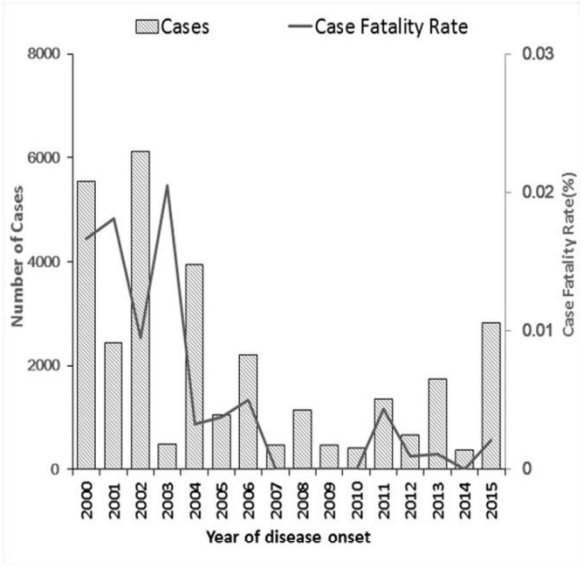
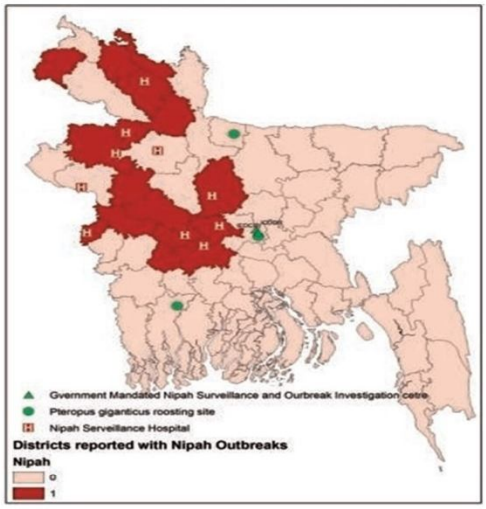
A.


Legend
Zoonotic disease infected districts
<all other values>
Dengue
0
1

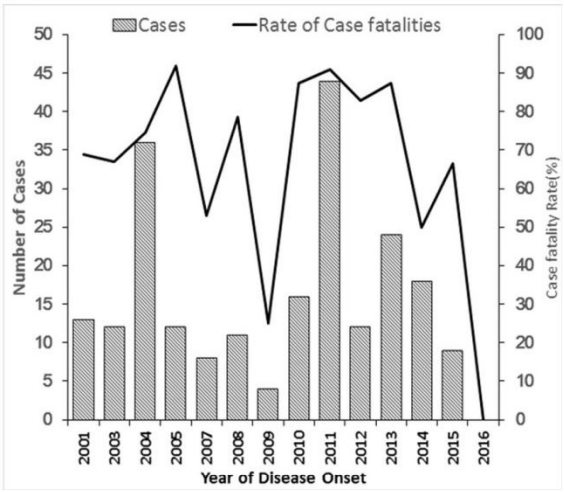
B.


Cases
Case Fatality Rate
Number of Cases
Case Fatality Rate(%)
Year of disease onset

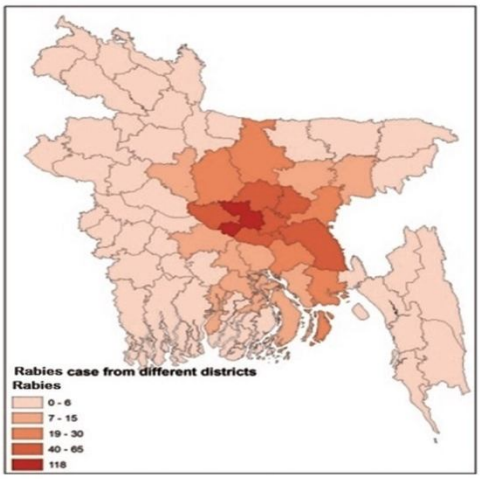
C.


Government Mandated Nipah Surveillance and Outbreak Investigation centre
Pteropus giganticus roosting site
Nipah Serveillance Hospital
Districts reported with Nipah Outbreaks
Nipah
0
1

D.


Cases
Rate of Case fatalities
Number of Cases
Case fatality Rate(%)
Year of Disease Onset

E.


Rabies case from different districts
Rabies
0 - 6
7 - 15
19 - 30
40 - 65
118

F.

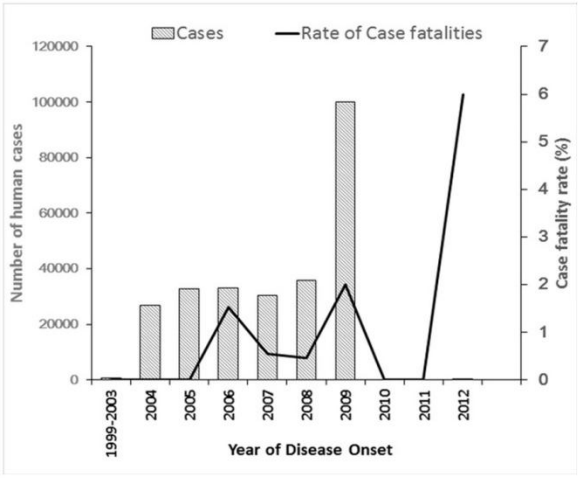
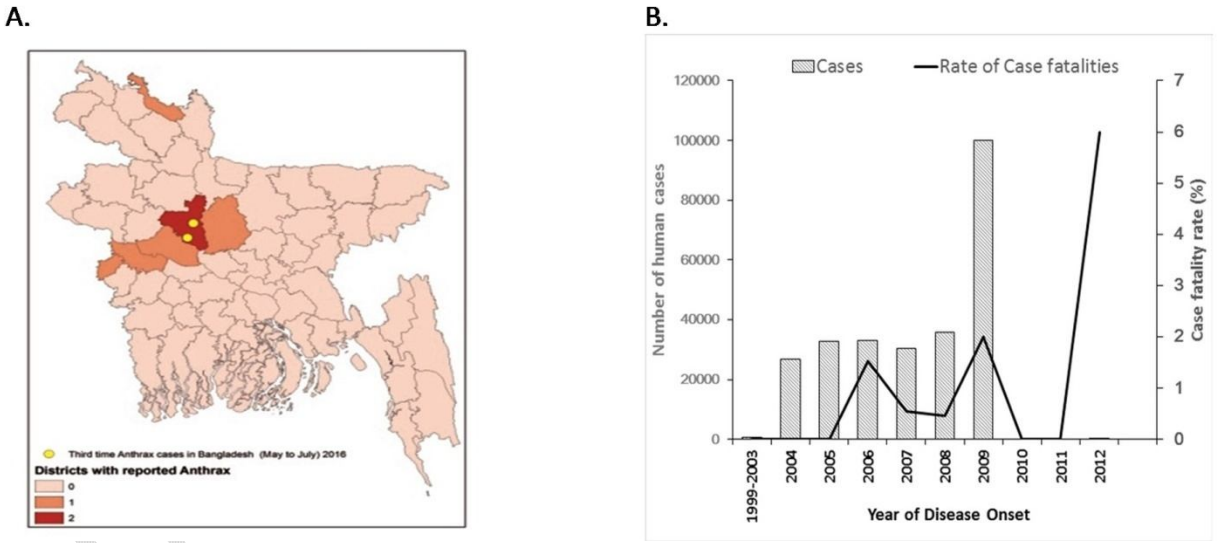

Cases
Rate of Case fatalities
Number of human cases
Case fatality rate (%)
Year of Disease Onset

Figure 2. Epidemiology of Nipah encephalitis, Dengue fever and rabies (A, C, E, respectively). Maps illustrate district distribution of the estimated number of diagnosed cases of Nipah encephalitis, Dengue fever and Rabies reported in humans, 2000-2016. The red regions together depict the Nipah belt because of the disease endemicity. Temporal distribution and of human Nipah encephalitis, Dengue fever and Rabies cases and mortality status in Bangladesh during 2000-2016 (B, D, F, respectively). For Nipah encephalitis cases, the morbidities and mortalities fluctuate independently and share no relation. Underreporting of cases events may have affected this outcome. For Dengue fever cases, the morbidities and mortalities after 2007 appear to increment with time. For rabies cases underreporting may have affected the outcome, since mortality was shown to increase, and negligible morbidity notifications have occurred in 2012. This finding may indicate an increased virulence of RABV affecting the recent victims.



E-REVIEW

Figure 3. Epidemiology of anthrax (A). Map illustrates district distribution of the estimated number of diagnosed cases of Anthrax reported in humans, 2000-2016. The red colored region at the center is known as the Anthrax Bbelt (B). Temporal distribution and of human anthrax cases and mortality status in Bangladesh during 2000-2016. The number of morbidities peaked in 2010 while the mortality rate peaked in 2011.

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Zoonotic Disease	Name	Pathogen	Seasonality	Risk factors	Treatment	Mode of transmission
Viral	Dengue fever	Dengue virus (DENV 1, DENV 2, DENV 3, DENV 4)	Monsoon—Early Autumn	Stagnant water bodies or pools Improper disposal of worn out tyres Water stored in large containers Climate change	Supportive care by analgesics, intravenous fluids, oxygen therapy, blood transfusion etc.	Mosquito vectors *Aedes aegypti* *Aedes albopictus*
	Nipah Virus Encephalities	Nipah virus (NiV - Bangladesh)	Late Autumn – Summer	Consumption of infected raw date palm sap and its beverages. Dermal contact with NiV infected patients Deforestation in rural areas Unawareness of hygiene maintenance	Supportive care	Saliva and Urine of fruigivore bats
	Rabies	*Lyssavirus*	Winter–Summer	Transdermal bite or scratch by infected dogs, foxes, Living in congestion	Local wound treatment Post exposure prophylaxsis by administering rabies immunoglobulin and vaccine Nervous Tissue Vaccine (NTV) Cell Culture Vaccine (CCV)	Saliva of an infected rabid animal Inhalation of virus containing aerosols (Rare) Tissue transplantation between humans
	Zika	Zika virus	-	Stagnant water bodies or pools Improper disposal of worn out tyres Water stored in large containers Climate change Emmigration of tourists, workers, refugees	-	Mosquito vectors *Aedes aegypti* and other *Aedes* spp.
Parasitic	Malaria	*Plasmodium falciparum, Plasmodium vivax, Plasmodium malariae, Plasmodium ovale*	Summer—Late Autumn	Stagnant water bodies or pools Blood transfusion with affected individual Usage of contaminate syringes amongst drug addicts	First line therapy for *P. falciparum* malaria : Artenine based compound treatments (ACTs) Artemether and lumefantrine, Incase of treatment failure Doxycycline+quinine Tetracycline+ quinine First line therapy for *P. vivax* malaria: Chloroquine and primaquine Therapy for severe malaria: Artemether and quinine	Mosquito vectors *Anopheles dirus*, *An. minimus*, *An. philippinensis*, *An. sundaicus*, *An. vagus* *An. karwari*, *An. maculatus*, *An. barbirostris*, *An. nigerrimus*, *An. aconitus*, *An. annularis* *An. baimai* Transmission via contaminated blood Transfer of infected blood from mother to fetus
Bacterial	Anthrax	*Bacillus anthracis*	Summer—Late Autumn	Direct contact, slaughter of infected livestock carcasses or being present at the site of slaughter Ingestion of infected livestock meat Grazing animals that forage on infected soil Living in congestion Bioaggression	Oral ingestion of antibiotics Ciprofloxacin Doxycycline Penicillin V	Contact with infected livestock carcasses or their products Spore Infected soil Inhalation of bacteria containing aerosols

Table 1. Zoonotic diseases of Bangladesh their pathogen, seasonality, risk factors, treatment and mode of transmission.

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