The West African Ebola Virus Disease Outbreak of 2014: Mapping the Journey of Confirmed Cases through Sierra Leone

by

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I. Problem Statement

Sierra Leone experienced the most severe Ebola Virus Disease Outbreak to ever impact West Africa in 2014. Over 14,000 confirmed, suspected, and probable cases of infection of the Ebolavirus were witnessed within the country. Sierra Leone has had a very tumultuous past and has been plagued with the mismanagement of both its economy and government for several decades. In addition, the country entered a very brutal and lengthy civil war in 1999 that did not end until 2002. The civil war caused substantial damage to the country as its population fell into extreme poverty, the nation entered into financial ruin which caused their educational system to collapse and their healthcare system to falter. After the civil war, Sierra Leone has been plagued with a corrupted and negligent government system that has been struggling to help advance the country economically and educationally (Nicol and Fyfe 2018). Because of these struggles, in early 2014, when the EVD entered the country, Sierra Leone was not prepared for what was about to befall upon them.

Sierra Leone is made up of 14 districts as seen in Figure 1: Kailahun, Kenema, Kono, Kambia, Koinadugu, Bombali, Tonkolili, Port Loko, Pujehun, Bo, Moyamba, Bonthe, Western Area Rural and Western Area Urban. Western Area Urban is home to Sierra Leone's capitol city of Freetown. Based on the country's turbulent past, over 60% of Sierra Leone's population lives below the national poverty line (UNDP 2018). As seen in Figure 2, almost every single district has over 50% of its population living below the national poverty line aside from Sierra Leone's capital of Freetown which expresses roughly 20% of its population in poverty (The World Bank 2013). The relationship between infectious diseases and poverty is evident as when poverty rates decline, infections rates are known to go up (Rees 2015). This has been witnessed in other fatal diseases such as malaria and tuberculosis (Reese 2015; UNICEF 2016).

In addition to extreme poverty levels, civil war collapsed both the educational and healthcare systems within Sierra Leone. By 2014, neither systems were advanced enough to be able to take on such a significant outbreak, especially one as deadly as EVD. A major reason for this is, there is a massive lack of healthcare workers (HCWs) in the country. Many HCWs fled the country during the civil war and for those that remained, the salaries were low, but workloads kept increasing which caused many more to leave. In addition, the lack of education within the country has created a very unstable healthcare infrastructure as many HCWs lack proper knowledge of the dangers of infectious diseases (Brady 2010). Furthermore, healthcare facilities within Sierra Leone are also deficient when it comes to preparation handling dangerous infectious disease such as the Ebola Virus Disease (EVD). Much of this is because of healthcare facilities being under-funded and under-resourced, which amounts to being unprepared for enormous outbreaks such as the one experienced in 2014 (Elston et al. 2016).

Urbanization is also a significant factor when it comes to high infection rates during infectious disease outbreaks. Highly populated areas such as the city of Freetown that has a population of over 1 million residents, or other mid to high populated districts such as Port Loko, which has the second highest population within Sierra Leone (Table 1), tend to become breeding grounds for outbreaks. The close proximity people have to one another and the increased interactions one may encounter in highly populated areas allow infectious diseases to spread rather efficiently (Alyanak 2017). In addition, human, animal, and trade good movements in and out of urbanized areas, throughout the country, and internationally can also allow infectious diseases to spread more readily (Patz et al. 2004). For instance, the EVD entered into Sierra Leone via human movement from its neighboring country of Guinea into the district of Kaliahun

as seen in Figure 3. This allowed the virus entry into the country and eventually Sierra Leone was completely inundated with the infectious disease (WHO 2016a).

In order to understand how Sierra Leone witnessed such high infection rates during the EVD outbreak, a comprehensive look into the country's road to poverty that left its healthcare system and education of its population vulnerable to infectious diseases and the effects of both urbanization and human movement during outbreaks will be analyzed. Both Sierra Leone Ministry of Health and Sanitation Situation Reports and the World Health Organization (WHO) Situation Reports issued during the outbreak will be examined in order to attempt to understand and review the following:

- To gain an understanding of how a poverty-stricken country with moderate urbanization may increase infection rates during outbreaks of EVD.
- To investigate if HCWs and healthcare facilities were successful at containing the outbreak through means of preparation.
- To understand if human movement affected infection rates within and in and out of cities and districts within Sierra Leone.

This directed research will help to establish if there is a connection between any of these factors. In addition, this research poses several questions surrounding poverty-stricken areas: Are urbanized areas more prone to higher infection rates? Will HCWs see high infection rates during the outbreak? Are healthcare facilities within Sierra Leone prepared for such a highly infectious disease? Lastly, does human movement increase infection rates during the outbreak of 2014? The questions present the following hypotheses:

- H_a: It is hypothesized that due to lower poverty levels high urbanization and/or human movement may cause significant infection rates during outbreaks of the EVD.
- H_0: It is hypothesized that due to lower poverty levels high urbanization and/or human movement will not cause significant infection rates during outbreaks of the EVD.

In addition, more hypotheses may be presented as well:

- H_a : It is hypothesized that the lack of preparedness, lower education, and/or the insufficient number of HCWs may cause significant infection rates during outbreaks of the EVD.
- H_0 : It is hypothesized that the lack of preparedness, lower education, and/or the insufficient number of HCWs will not cause significant infection rates during outbreaks of the EVD.

By answering these questions and evaluating these hypotheses, a greater understanding of how poverty-stricken countries are more vulnerable to immense outbreaks of dangerous infectious diseases such as the EVD will be developed. It is believed that highly urbanized areas will see high infection rates and well as areas that experience even minimal human movements in and out of infected areas. In addition, it is also believed that healthcare facilities will be ill-prepared for the magnitude of this EVD outbreak. This directed research may help to increase the awareness of how vulnerable poverty-stricken countries such as Sierra Leone are when it involved such deadly infectious diseases like that of the EVD.

II. Background

The Ebolavirus is classified as being members of the virus family known as Filoviridae (or filovirus) which can cause a severe viral hemorrhagic fever in both humans and nonhuman primates. The virus first emerged in northern Zaire (now known as the Democratic Republic of Congo) near the Ebola River in 1976 (Rizkilla et al. 2007, 152; CDC 2014a). During the time of its discovery, only one other filovirus was known to have existed: Marburgvirus. While Marburgvirus and the Ebolavirus are extremely similar with signs, symptoms, transmission, infection rates, and fatality rates, their genomes are different enough to be considered two separate viruses. However, the Ebolavirus is known to have significantly higher infection and fatality rates (CDC 2014b; CDC 2014c). The term Ebolavirus encompasses all strains of the virus and each strain of the virus has its own unique name. Currently, there are five known strains of the virus with each carrying their own fatality rates: Ebola virus (formerly Ebola Zaire), Sudan virus, Tai Forest virus, Bundibugyo virus and last the Reston strain of the virus which is the only strain that causes disease in nonhuman primates as it does infect humans as it is asymptomatic and possess no real threat. The Ebola virus has the highest fatality rate of all of the strains which is nearly 90%. Outbreaks have occurred since the EVD's emergence in 1976 in the Congo in 1977, 1995, and 2007, and also within the countries of Sudan in 1976 and 1979, Gabon in 1996 through 1997, Uganda in 2007, England in 1976, Virginia in 1989 (non-human strain of Ebola Reston that only infected primates) and Ivory Coast in 1994 (Oldstone 2010, 214-220).

Infection of the virus occurs due to direct contact through broken skin, mucous membranes such as the eyes, nose, or mouth, or by limited exposure through the air under specific conditions (Chowell and Nishiura 2014; CDC 2016a). Signs and symptoms of EVD

include fever, severe headache, muscle pain, weakness, fatigue, confusion, diarrhea, vomiting, abdominal pain, and unexplained hemorrhages (bleeding or bruising). Most signs and symptoms will appear anywhere from 2 to 21 days after an individual has been exposed to the virus. In some cases, individuals who are exposed to the virus may be quarantined for 21 days to prevent them from being able to spread the infection. If the person has not experienced any of the signs and symptoms of the virus during that time, the individual is considered healthy and the quarantine is lifted (CDC 2014d). As exposure time increases the symptoms become more severe and in some cases the infection will cause death. Some signs and symptoms are not seen in all patients, especially those patients that were able to have proper treatment, maintain adequate hydration and ultimately survive the EVD (Schieffelin et al. 2014). However, a limited number of patients did experience some signs and symptoms such as bleeding from the mouth, rectum, eyes, ears and nose. In most cases this was due to the patient nearing the end of the infection and resulted in the patient's death through organ failure (CDC 2014d).

It is thought that fruit bats are the Ebola virus's natural reservoir as bat migration patterns have been studied and linked to outbreak occurrences of the virus (Hassan et al. 2016, 518). Although a bat has never tested positive for the virus, serum antibodies specific to the virus were found within three different bat species that are unique to Africa (Han et al. 2015, 3). There are currently 39 known bat species in Africa. Although they all maintain similar migration patterns, some bat species tend to migrate to other locations around Africa in comparison to their sister species. Prior to the Outbreak in 2014, there had never been a location in Africa of an Ebolavirus Outbreak that had migratory patterns unique to a limited number of the 39 species of bats. However, as the Outbreak began to occur in West Africa and the theory behind fruit bats being the virus's natural reservoir, research began to determine if that portion of Africa had

unique bat species. Fortunately, of the 39 species currently found in Africa, only 13 are present in West Africa where they are normally found within the rainforests and forest-savanna mosaics. Those 13 species were currently migrating in the area when it was believed the Outbreak began. Not only did this further the theory that bats may be the natural reservoir of the Ebolavirus, but it also may help to determine which specific bat species could potentially be the natural host of the virus (Hassan et al. 2016).

Under normal circumstances, bats do not usually have much contact with humans as they do not tend to intrude on bat's specific niches. There have been some cases of children playing in trees that house bats (Saez et al. 2014, 3). However, bats have a higher likelihood of interacting with nonhuman primates such as gorillas and chimpanzees in the wild. This is because bats and many non-human primates located in Africa compete for the same types of fruit during the dry seasons (Rizkilla et al. 2007). If bats are in contact with these animals, it is highly likely that they can transmit the virus to them. This is known as a spillover event. Spillover events occur when the host species of a specific pathogen infects another species and that infected species falls ill (CDC 2016c). Gorillas, chimpanzees, and, in some cases, bats are often killed for their meat, known as bushmeat, in many African nations. Carcasses are handled and consumed by the local populous (Rizkilla et al. 2007). If the carcass was infected with the EVD, there is a high likelihood that those consuming the meat of the carcass will become infected as well. This is the ongoing assumption of how many of the outbreaks have occurred in Africa in the past (Rizkilla et al. 2007, 151).

On December 6, 2013 a two-year-old boy in the village of Meliandou in Gue´cke´dou Prefecture, Guinea, died of what was believed to be the EVD (Gatherer 2014, 1621). Through detailed observations it was discovered that some hollow trees were located near a walking path

that residences of the village would take on their way down to a water source to wash their laundry. Some believed that the hollow trees housed bats. It was said the little boy would sometimes play within the trees and it is assumed that this is how the boy became infected with the virus in late 2013. Although, the direct action of exposure to the boy has never been discovered as the boy may have been bitten, the boy might have come in contact with the bodily fluids of the bat through feeding or handling that may have infected the child, or perhaps the boy had contact with bat dropping (Saez et al. 2014, 3). The child became ill and eventually died from the EVD. However, it is unclear if anyone in the village was aware that the boy had the Ebolavirus. After the boy died, the virus continued to spread to Macenta, Guinea and Kissidougou, Guinea. Again, it is unknown if those infected within these cities realized they had the EVD or if they thought it was the common flu that these individuals had (Baize, et al. 2014). Either way, as the EVD spread throughout Guinea it went relatively unnoticed until February of 2014 when the Ebola Outbreak of 2014 was first officially declared. By March of 2014 EVD had spread to Guinea's neighboring country of Liberia and by April of 2014 Sierra Leone began reporting EVD cases. By February of 2016 over 28,000 cases of reported infection and over 11,000 deaths across 9 countries were reported with Guinea, Liberia and Sierra Leone experiencing the highest infection and mortality rates: 3,804 cases with 2,536 deaths, 10,675 cases with 4,809 deaths, and 14,124 cases with 3,956 deaths respectively (HealthMap 2017).

III. Literature Review

i. Sierra Leone's Road to Poverty

To gain a better understanding of how Sierra Leone might have been susceptible to such an extensive outbreak, a bit of history must be investigated. First, largescale poverty on a society can have many crippling effects. It has been known that poverty can cause an increase in a population's hunger, deny access to clean water, deliver poor education, increase in illness, poor sanitation measures, decreased household income, and even poor housing (Shelton 2016). Also, poverty is considered one of the greatest risk factors when it comes to acquiring and succumbing to diseases worldwide. This is especially true during any type of large scale epidemics as a country stricken with poverty may experience catastrophic effects during outbreaks of disease such as the EVD (Alsan et al. 2011).

Sierra Leone has had a tumultuous past both politically and economically that has left 60% of the country's population of over 7 million living below the national poverty line. Most of the population lives on less than $1.25 a day (UNDP 2018). In 2017, Sierra Leone was stated as being the 14th poorest country in the world with a gross domestic product per capita of $1,651 and a per capita income of $684 (Tasch 2017) (UNDP 2018). In order to fully understand how Sierra Leone has fallen into poverty, a comprehension of the country's past is necessary.

After more than 150 years, Sierra Leone, the last West African state to be under colonial rule, peacefully gained its independence on April 27th, 1961 from Britain (BBC 2018). Sir Milton Margai became the nation's first Prime Minister. During his reign, the first years of the nation's independence was prosperous (Nicol and Fyfe 2018). Mineral resources such as iron ore and diamond mining brought considerable revenue to the country which was used for development and education (BBC News 2017). The future of Sierra Leone, being its own

independent country, seemed optimistic at this point. However, in 1964 Maigai died and the years after his death, political leaders and government regimes shifted. Iron ore was being depleted in astronomical rates and became exhausted, while diamonds were being smuggled out of the country (Nicol and Fyfe 2018). Eventually, because of these activities, Sierra Leone's economic revenue was gone, their educational system had begun to collapse, and the political regimes became corrupted and mismanaged. Also, rogue rebel military groups, being funded by the diamond smuggling, began to form in Sierra Leone due to the conflicts surrounding maladministration that was taking place within the government (Sesay and Nicol 2017).

By the early 1990's Sierra Leone's civil society had become weak and dissatisfied due to the mismanagement of both the government and economic revenue (Nicol and Fyfe 2018). In 1991 a conflict occurring in Liberia, a neighboring country, spilled over into Sierra Leone. With the nation's society being in its weakened state and rouge rebel groups scattered throughout the country, this spillover instigated a very long, brutal, and costly civil war which lasted from 1991 to 2002. During this time, at least 50,000 people died, over two million people were displaced, and hundreds of thousands more were affected by the violence the civil war brought to the country (Sesay and Nicol 2017). Poverty was able to creep its way into Sierra Leone's society leading up to the civil war due to prolonged periods of economic decline and governmental mismanagement. The civil war exacerbated the magnitude and severity of poverty within the country (Aguayo, Scott and Ross 2003). As the economy was deteriorating prior to the war, the war itself halted any type of economic development (Worley 2017; Nicol and Fyfe 2018). In 2013, the World Bank confirmed, as seen in Figure 2, all districts, minus the capitol city of Freetown, expressed over 50% of the population was experiencing poverty (The World Bank

2013). Freetown, in comparison to the other districts, witnessed 20% of its population in poverty.

Poverty has been linked to an increase in infection rates regarding a number of infectious diseases. As poverty increases, infections usually increase as well (Rees 2015). For example, Malaria is known as the disease of poverty as it primarily affects poverty-stricken areas that lack proper constructed housing that contain barriers against mosquitoes, the insect responsible for carrying the disease. Over one million people die annually across the world due to Malaria but over 90% of the fatalities and infections are located in areas of extreme poverty (UNICEF 2016). Another example is that of tuberculosis, a highly contagious airborne disease, which result in over two million deaths per year. Again, 98% of the deaths associated with tuberculosis are located in developing countries that are usually stricken with high poverty levels (Rees 2015). As Sierra Leone entered into extreme poverty following its civil war, the country inadvertently allowed itself to become a breeding ground for EVD.

The purpose of this study is to see if a poverty-stricken country such as Sierra Leone may have experienced high confirmed infection rates due to poverty alone or if poverty enabled other factors such as vulnerable healthcare systems or urbanization to cause higher infection rates.

ii. Preparedness of Healthcare Facilities and HCW's in Sierra Leone

A side effect of high poverty rates and a failing economy is the vulnerability of the healthcare system within Sierra Leone. The healthcare facilities pose a significant threat to largescale outbreaks. Sierra Leone lacks an advanced healthcare system and many of the facilities are under-funded, under-resourced, experience lower education of its HCWs, and lack normal sterilization materials such as gloves, gowns, soap, or clean beds (Elston et al. 2016). The lack of beds is a major concern when it comes to any type of EVD outbreak as beds are

needed for treatment but are also used to set up appropriate triage areas which are designed to improve the safety of the patient and to correctly isolate them from HCWs, patients, and other individuals within healthcare facilities while still maintaining care to the infected (WHO 2018a). By not having enough beds, people were turned away from treatment centers because they were full. Healthcare facilities could not handle the massive number of patients that were coming in. The more people a potential EVD patient comes into contact with, the larger the chain of transmission becomes. Chains of transmission, as seen in Figure 4, are when a single individual may become infected with a pathogen. Everyone they come into contact with has the ability to become infected as well and become part of the chain. Chains of transmission are followed very closely if they are able to be discovered during epidemics and the chains are then isolated in hopes of breaking the chain which may substantially decrease the number of infected during an outbreak. Individuals that are part of chains of transmission are usually asked to voluntarily put themselves into a 21-day isolation (WHO 2018b). As previously mentioned, 21-days is the normal incubation period of the EVD (CDC 2014d). By using a 21-day isolation, this ensures the chain of transmission is broken (WHO 2018b). When healthcare facilities are unable to put those infected into isolation, the chains of transmission become so massive it is nearly impossible to isolate and break the chain (Kucharski et al. 2015). For example, the young child represented in Figure 4 came in contact with his sister who came into contact with their grandmother, mother, and a family friend. Eventually, the chain of transmission included 30 individuals which started out with one single child (WHO 2018b). This is an example of how chains of transmission can significantly change the outcome of a highly infectious outbreak.

In addition to the lack of advancement and under-paid, under-resourced, and overburdened hospitals, many other factors may contribute to high infection rates during an

outbreak. In many instances HCWs are not prepared nor are they educated and knowledgeable when it comes to the EVD. Several studies have been conducted concerning the education and knowledge of HCWs concerning the EVD. One such study was conducted in India where they questioned the HCWs at a specific hospital to see if they understood the EVD and what it is capable of (Ahmad et al. 2016, 751). Although the HCWs understood that the EVD is a serious illness, many of them were unaware of how the virus is transmitted, that protective equipment such as gloves and masks should be worn while administering care to those infected with EVD, or that those infected should be kept in isolation. The lack of knowledge at this particular hospital could potentially lead to higher infection rates at this location if a patient were to be admitted that was infected with EVD because the HCWs do not know the procedures of how to treat it. This was the case for many of the facilities that cared for EVD patients in Sierra Leone (Elston et al. 2016, 61). Another example of how preparation may affect infection rates took place in the U.S. Two U.S. hospitals took in EVD patients that had been infected with the virus in West Africa. One hospital, Emory University Hospital (Emory) was semi-prepared for the arrival of a patient from West Africa (Woods 2016). The patient was an American doctor who was working at an Ebola Care Unit in Monrovia, Liberia. Shortly after the doctor fell ill he was transported to the United States where he immediately was admitted into the Serious Communicable Disease Unit at Emory. Emory was given ample time, fair warning and already had a unit specifically designed to deal with such a dangerous and virulent disease (Lyon et al. 2014). Texas Health Presbyterian Hospital (THPH) was another hospital that had cared for a man that was originally from Liberia and had just recently flown to Texas. This man had been exposed and caught EVD in Liberia. THPH had mistakenly diagnosed the man with sinusitis, a respiratory infection, and was released from the hospital. During this time, he was exposing an

unknown number of individuals to EVD. Shortly thereafter his illness became worse and he went back to the hospital that had finally discovered his true diagnosis: EVD. The hospital was not ready, they did not have a unit specifically designed for the care of EVD patients, and they did not have proper protocols in place that could prevent potential exposure to HCWs or any of faculty. Needless to say, a nurse was inadvertently exposed to the EVD and had eventually fallen ill. Thankfully the nurse survived the EVD, but it shows how a slip in protocol, a hospital that was not prepared, and did not have the appropriate facilities on site could put HCWs and other populations at risk of catching the virus (McCarthy 2014). The infection rates differed between both locations because one location was prepared whereas the other was not.

The more prepared, educated and knowledgeable the healthcare facility is, the less likely for infection to spread at a specific location. In August of 2014 Nigeria was struck with probable cases of the EVD but by the end of September of 2014 the country was considered free of the virus (HealthMap 2017). Reasons behind such a short outbreak of the EVD within Nigeria are given to the education and advancement of both the healthcare facilities and the HCWs of the country (Ohuabunwo et al. 2016, 27). They were better equipped for the EVD which prevented not only the HCWs from becoming infected, but it also prevented enormous chains of transmission to form and become untraceable in order to isolate and break the chains. By simply being prepared and educated allowed the country, the healthcare facilities, and the HCWs to prevent a massive outbreak. Today there have been attempts to further educate HCWs of the EVD in healthcare settings. The WHO and the Centers for Disease Control and Prevention (CDC), and the Occupational Safety and Health Administration (OSHA) has responded to the outbreak by creating an Interim Guidance Report for HCWs to prevent and control infections of suspected and confirmed hemorrhagic fevers in health-care settings (WHO 2014a). The report

focuses on response times, sanitation protocols, handling, treatment and transport of EVD patients, and many other recommendations for protecting HCWs when they come in contact with infectious diseases (OSHA 2018). In addition, educational programs for nursing students have been developed in the US to help educate more HCWs of the dangers of EVD (Ferranti et al. 2016, 598).

This directed research could potentially show areas within Sierra Leone that may experience high infection rates. If these infection rates are increased in areas that lack proper EVD protocols, educated HCWs and faculty of healthcare facilities, or if these areas have a generally lower educational system, it could offer an understanding of why high infection rates are occurring within these areas. This understanding could potentially lead to developing methods to increase education, awareness, and/or protocols of EVD during outbreaks.

iii. Population Movement During Infectious Disease Outbreaks

On top of poverty and a suffering healthcare system, highly urbanized cities such as Freetown, are efficient at becoming incubators for infectious diseases (The World Bank 2013) (Alyanak 2017). Movements of humans, agricultural products, regional delicacies such as bushmeat, domestic animals such as chimps, gorillas, or fruit bats, and other trade goods in and out of urbanized areas is frequent and ongoing (Patz et al. 2004). This can potentially cause significant effects of increases in infection rates that other areas may not experience during an outbreak. An example of intra-city movement of both humans and domestic animals occurred in 1999 as a city in Malaysia experienced a combination of deforestation, an extensive drought, and dangerous wildfires in urban areas. This led to alterations of movement for both the human population and their cattle within the city-region. Wild large fruit bats, known to be a reservoir of the Nipha virus, were given the geographical opportunity they had not experienced beforehand

to come in contact with pigs that were moved by farmers during the alterations of population movements. The pigs became infected with the virus and, in turn, farmers and other people who came in contact with the pigs became infected as well. This created a substantial outbreak of the Nipha virus (Chua et al. 1999).

In addition to movement within cities, human movement in and out of cities has significant consequences for public health as well. Travelers, such as tourists, businesspeople, or visiting family members may put themselves at risk of becoming infected with a communicable disease. Once they become infected, they have the potential of becoming vectors by delivering the infectious diseases to another region after they leave an urban city, such as Freetown (Patz, et al. 2004). As previously mentioned, those that are infected create a chain of transmission. Without isolating the chain and breaking the transmission of the virus, infection rates will continue to increase (WHO 2018b).

Unfortunately, undiscovered chains of transmission occurred during the EVD outbreak in September of 2014. As mentioned previously, a man traveling from Liberia, a country that was currently being ravaged by the EVD at the time, came to the United States. He had become infected in Liberia with EVD but showed relatively little to no signs and symptoms aside from a mild fever. He was on U.S. soil for 5 days before he began to show the classic signs and symptoms of the disease. It is unknown if he was symptomatic during those 5 days, but he became an unknown chain of transmission. However, because he was sick he sought medical attention at a Dallas hospital. Several HCWs had been in direct contact with the man during his visit to the hospital which increased the chain of transmission. A nurse that had been in direct contact with him became infected with the EVD. The man died but the nurse survived. As soon as the nurse became symptomatic and fell ill she was immediately put into isolation. In addition,

anyone that had come in contact with her was put into a voluntary isolation for 21-days. This chain of transmission went unknown until the man was diagnosed and once the nurse and all of those that came in contact with the nurse were in isolation, the chain of transmission was broken and the infection was eliminated (CDC 2014e; Kucharski, et al. 2015; WHO 2018a).

As of 2015, over 1 million people are said to live within the Western Area Urban district of Sierra Leone, which is primarily made up of Freetown. In addition, the entire country is home to over 7 million people (Sierra Leone Census 2015). Any type of human movement that can potentially contain both known and unknown chains of transmission within a country that is this populated could potentially be catastrophic. Therefore, this directed research is going to examine, through tracking each district within Sierra Leone, confirmed infections as they progressed throughout the country over the entirety of the outbreak of 2014. It may help to understand how inter- and intra-population movements affected confirmed infection rates for each region and the country as a whole.

iv. Survivors of Ebola: The Stigma and Long-term Effects of Surviving the EVD

Many diseases have placed stigmas on people, communities, and even entire societies in the past (Davtyan, Brown and Polayan 2014). An example of this is the HIV epidemic as both people that are infected, or during the initial stages of the HIV/AIDS epidemic, homosexuals were stigmatized by strangers, their communities or even their families (Avert 2017). Unfortunately, the survivors and caregivers of EVD are experiencing much of the same type of discrimination, stigmatization, and even criminal actions against them following the EVD outbreak (Davtyan, Brown and Polayan 2014). Survivors are being shunned from returning to their homes, some have lost their jobs, and even friends and family have rejected them. Society within countries that experienced widespread outbreaks such as Sierra Leone have experienced

some cases of civil unrest and even violence against survivors or individuals such as family members or HCWs that have cared for EVD patients. There have also been reports of killings associated with the stigma surrounding survivors of the EVD (Yadav and Rawal 2015). Much of this stigmatization is because people and communities fear contracting the virus from the survivors even though the survivors are no longer contagious (Davtyan, Brown and Polayan 2014). Due to these types of situations, many survivors experience mental health challenges (Yadav and Rawal 2015).

Survivors are left with a deep depression as they attempt to integrate themselves back into society. Many are faced with discrimination upon their return to society and become plagued with extreme anxiety. In addition, survivors and caregivers are often haunted with the traumatic experiences they had while being treated in healthcare facilities, witnessing their loved ones fighting EVD, or the deaths of their friends or family members they witnessed during the outbreak (Yadav and Rawal 2015). Often, survivors resort to alcohol use, a dependency to drugs, and suicidal behaviors in order to cope with the anxieties of social acceptance. Survivors, caregivers, widowers, and any orphaned children fall into a post-traumatic stress syndrome following outbreaks (WHO 2016b).

In addition to social integration and the difficulties of that, survivors also deal with several health problems following the EVD. One of the significant issues survivors face is musculoskeletal pain is noted in 50-75% of survivors. As the virus ravaged their bodies during infection, it also broke down many of the survivor's muscles and joints. Another common health problem survivors develop is eye issues including eye pain, dryness, sensitivities to light, and even blurred vision. In limited cases, especially in the elderly, retinal scarring occurs which decreases their vision, or the individual has lost their vision entirely. Hearing issues also occur

in over 25% of EVD survivors which includes hearing loss and tinnitus or ringing in the ears. Neurological issues are also quite common in EVD survivors. Many experience tremors, seizures, and headaches including migraines upon recovery for the rest of their life. Sexual health is also severally altered for survivors of EVD. Many men experience erectile disfunction and testicular pain (WHO 2016b). On the other hand, women are prone to having significant changes in their menstrual cycle such as missed periods, early menopause, and unusually long or heavy cycles (WHO 2016b; NMIHI 2018).

Although most of these sexual health problems associated with EVD occur directly after and for the years following the infection, men are still at risk of infecting someone with the virus for some time after their initial recovery. Tests conducted after recovery from EVD have shown that a man's semen may contain the virus for up to 6 months. Although this it is rare for the virus to be passed on via sexual intercourse, it has occurred previously. It has been strongly advised for men to use protection or sustain from sexual contact until they have been cleared of the virus via semen (Deen et al. 2015). Men are usually offered testing for some time after their recovery of EVD to ensure they are clear of the virus before they are advised to have unprotected sex (Deen et al. 2015; CDC 2016b). In addition, vaginal fluids from a woman have tested positive for the virus up to 33 days after recovery. However, viral vaginal fluids have yet to be a confirmed case of being a mode of infection (WHO 2016b).

Survivors, caregivers, and the family and friends of survivors are faced with a long road of health problems, mental illness, and stigmatizations from society. As previously mentioned, this EVD outbreak is not the only disease to experience this type of treatment. However, in 2015 many agencies including the WHO and the Ministries of Health in countries that were involved with the outbreak in West Africa have begun developing a survivor's framework that is essential

for the care of EVD survivors. It helps to identify the care and needs of survivors when it comes to their ongoing health issues, vaccines they may need in the future, health screenings for ailments that are directly linked to being infected with EVD, to improve their quality of life, and to help address any mental health issues they may have or have developed due to the outbreak. In addition, the WHO has also created a semen testing program for EVD survivors. Currently, over 1,200 men have been enrolled in the program (WHO 2016c).

Recovery is an ongoing process but a much needed one. Although this study may not directly address the stigmatization, health problems, mental health problems, and sexual health issues of survivors, family and friends of survivors, and HCWs experience after an outbreak, it is important to understand that it does happen. The study will touch upon the timeframe in which these issues begin to address these ongoing problems.

IV. Research Methods

In order to gain an understanding of how the EVD Outbreak of 2014 progressed throughout Sierra Leone, a mixed method approach will be utilized by using both quantitative data and qualitative explanation of the progression of the EVD throughout the country over the time period of May 20th, 2014 through May 31st, 2016. To achieve this, several methods were applied to this study. These methods included the use of secondary data that was utilized for data collection from multiple sources. The data was filtered, sorted and organized into independent quarterly timeframes. The data was imputed into the program of ArcMap 10.6 to create maps to visually express the journey of infection as it moved within the country through time. Once the maps were completed, they were visually inspected and were compared with the Sierra Leone and WHO's Mortality Reports to gain a qualitative understanding of how confirmed infection rates may have increased or decreased over time through each district of the country and the country of Sierra Leone as a whole.

i. Data Collection – Situation Reports

The data was collected from the following institutions via Situation Reports: Sierra Leone Ministry of Health and Sanitation and the WHO (Sierra Leone Ministry of Health and Sanitation 2014; WHO 2014b). The WHO Situation Reports were created by WHO, the United Nations Children's Fund, and the International Federation of the Red Cross and Red Crescent Societies. At total of 246 reports were investigated with 178 being from the Sierra Leone Ministry of Health and Sanitation Situation Reports and 68 being from the WHO Situation Reports. For all reports, only confirmed cases of infection of the EVD were used in this study.

Sierra Leone's Situation Reports (SLSR) began on August 13th of 2014 and ended on April 14th of 2015. The SLRS were given on a daily basis; however, many days during that time

period were skipped. The SLSR began with Volume 78 and ended with Volume 321. Volumes 1 through 77 were unable to be located and were therefore not used and a total of 67 volumes between volumes 78 through 321 were missing. Even though volumes 1 through 77 were missing, volume 78 had information prior to the August 13th date which was that of May 20th. The report gave a cumulative number of confirmed cases from May 20th until August 13th. Therefore, May 20th marked the first date that was used for this study. The WHO's Situation Reports did not begin until August 29th of 2014 but they surpassed SLSR's as they ended on June 10th of 2016. The WHO Situation Reports were provided on a weekly basis.

All SLSR's had tables and data that provided extensive information regarding the outbreak which ranged from summary highlights, number of deaths, number of beds used in each district, etc. Not all reports contained this as some did, and some did not. For the purpose of this study, the table that was titled "National Cumulative summary of Ebola Cases [Date/Timeframe]" was used. In some reports it was labeled as Table 1 whereas others it was labeled as Table 2. Within this table, only confirmed cases that are located in the column highlighted in red in Figure 5 were used for each district. It is important to note that these reports were very basic at the beginning of the outbreak but as the outbreak progressed, the reports become more extensive and provided more information.

For the WHO Situation Reports, it began similar to the SLSR as the first reports were vague and contained minimal information. However, as the outbreak progressed, the data became more extensive as it included information similar to the information provided from SLSR's. The WHO Situation Reports also included data from each country that was currently experiencing any type of infections during the specific timeframe of the report. Only information regarding Sierra Leone was used for this study from these reports. Unlike SLSR's,

the data was not given in a table with the WHO Situation Reports. Rather, the data was provided in a summary paragraph(s) which included highlights of how EVD transmissions were occurring, specific confirmed infection rates for each district, number of beds available, and other types of useful information regarding the outbreak during that specific timeframe. Although the WHO Situation Reports did give information on Sierra Leone, it sometimes did not include all of the districts within the summaries even if confirmed cases were present within those districts.

ii. Data Collection – Quantitative Data Organization

The data was organized in quarterly form per district within Sierra Leone as per Tables 2 and 3. The quarters for the years of 2014 through 2016 that were chosen were as follows: June 1st – August 31st, September 1st – November 30th, December 1st – February 28/29th, and March 1st – May 31th and, with the data provided, May 20th – May 31st was used for the year 2014. For 2014, data was available beginning on May 20th via SLSR Volume 78, but the data was given in cumulative form from May 20th till August 13th which is a total of 86 days. In order to extrapolate this data to fit into a quarterly fashion, it was assumed that the number of confirmed cases that occurred during this time period of 86 days was uniformed. Therefore, May 12th-31st is 14% of the 86 days provided which allowed 14% of the confirmed cases for each district to be allotted to fit into the May 20th-31st 2014 quarter. All other quarters were organized independently from one another. In other words, June 1st – August 31st of 2014 did not include the May 12th-31st quarter's confirmed cases. The confirmed cases for each quarter are only the cases found within that specific timeframe.

Since the WHO Situation Reports did not begin until August 29th, 2014, data organized before then was strictly via SLSR's. However, the first WHO reports were very lacking as they did not provide extensive data and the data that was provided was incomplete, very broad, or it

did not express information about each district individually. Therefore, WHO Situation Reports were not used for quantitative data organization until the December 2014 – February 2015 quarter. The December 10th, 2014 WHO Situation Report was the first report used for quantitative data organization. From this point on, both SLSR's and WHO Situation Reports were used in combination with one another. Quantitative data from both reports were compared and the data that was similar on both was recorded. For data that was confusing or incomplete on one report, the other report was used to fill in information and gaps.

For the SLSR's, some data was not provided at all. For instance, as previously stated, 67 volumes of the reports were missing entirely. If the WHO Situation Reports could not fill in the gaps of confirmed cases during these missing volumes, the method used to extrapolate data for the days missing was by using both the volume directly before and the volume directly after the missing volume. By comparing the cumulative confirmed cases on each of those volumes, basic calculations of subtracting the confirmed cases from after the missing volume(s) from the confirmed cases before the missing volumes gave the confirmed cases of the missing. An example of this is as follows:

Example:

DISTRICT	CUMULATIVE CONFIRMED FROM VOLUME 1	MISSING	CUMULATIVE CONFIRMED FROM VOLUME 3
PORT LOCO	25	?	30

Missing = 30 -25 = 5

In addition to this, on some occasions, both the WHO Situation Reports and the SLSR's provided slightly different data. For example, one report may have stated 11 confirmed cases

were documented in the district of Kenema in a specific week/day whereas the other report said 15 were documented. The report that had more reliable summary highlights of infections and transmissions were used. In most cases, for data in the beginning of the outbreak, the SLSR's were used and as the outbreak progressed and the WHO Situation Reports became more thorough and specific, the WHO Situation Reports were used. It is important to note that the WHO Situation Reports did have a large discrepancy for the week of February 15th, 2015. The WHO Situation Reports claimed there were 74 confirmed cases between all districts for the week. However, SLSR's claimed there were 91 confirmed cases for all districts. The WHO issued a correction the following week stating they did not obtain the missing confirmed cases that were present in the SLSR's until after their report had been published. So, it was important to fully investigate reports before, the day/week of, and after each volume to maintain proper confirmed cases throughout the outbreak. Once the data had been organized as seen in Table 2, the data was converted to percentages in order to map out each quarter independently from one another as per Table 3.

iii. Map Creation

Maps were created in order to give a visual representation of the data in Table 3. The program ArcMap 10.6 was used in order to achieve this. A total of 9 maps were created as seen in Figures 6 through 14 which offers a visual representation of this data. To create each map, shapefiles of the 14 districts of Sierra Leone were used and obtained from the Humanitarian Data Exchange via the Government of Sierra Leone (Government of Sierra Leone 2018). In addition, shapefiles for the countries Liberia and Guinea were obtained from the Humanitarian Data Exchange as well (UNMIL 2017; World Food Programme 2017).

Once the maps' primary layers were created, the attribute table for the Sierra Leone districts was edited for each map to include a column for "confirmed" cases. Percentage data from Table 3 was utilized and was implemented for each district into the map layer. A color gradient ranging from dark green to deep red was applied to show a visual interpretation of confirmed cases within each district. The confirmed cases gradient expressed 7 classes: 0.00%, 0.01% - 15.00%, 15.01% - 30.00%, 30.01% - 45.00%, 45.01% - 60.00%, 60.01% - 75.00%, 75.01% - 100.00%. The class 0.01% - 15% was used in order to show minimal confirmed cases. Even if a district had only 1 confirmed case during the specific quarter, it was expressed as being greater than 0% to show confirmed cases were present within the district. A map was created for each quarter and all maps are independent from one another.

iv. Qualitative Data

All data that was incorporated into the maps, tables, and figures have been that of quantitative data. However, qualitative data was utilized in the interpretation of the maps and the understanding of how the transmission of confirmed cases traveled throughout the districts of Sierra Leone during the EVD outbreak. The SLSR's were used to strictly obtain quantitative data. However, the WHO Situation Reports were used for both quantitative and qualitative data. The WHO had an archive of all situation reports that were used in this study (WHO 2016a). As stated, they were offered on a weekly basis. At the beginning of the outbreak the WHO Situation Reports did not give much summary information of the outbreak as it was occurring. However, as the outbreak progressed, more information became available. The information used was the chains of transmission, how many confirmed cases were being discovered during each report, the number of beds Sierra Leone had compared the number of beds that were needed, the number of HCWs becoming infected, and any other information that seemed viable in understanding how each district within Sierra Leone was responding to the outbreak. For each Situation Report,

only Sierra Leone was investigated as no other country was looked at even though the information was available. In addition, any background information or any information developed in the literature review was utilized to comprehend and fully understand what was occurring in Sierra Leone as the outbreak progressed.

v. Data Error Disclaimer

It is important to note that most of the data used in this directed research is secondary data, by using secondary datasets, mistakes or missing information may be present within them. This may limit the information being provided and it may alter the outcome of the results. Also, the data was being taken during very chaotic and turbulent situations which may prevent the data from being entirely accurate. However, the WHO and the Sierra Leone Ministry of Health and Sanitation are reputable entities that would not intentionally provide inaccurate data. Any data that is inaccurate is coincidental and not the fault of the entities providing the information.

V. Results & Discussion

Note: *All quantitative data that is mentioned within the Results & Discussion section refers to Tables 2 and 3 located in the Appendix. Number of actual confirmed cases is reflective of Table 2 while percentages is reflective of Table 3. All mention of this data is reflective of the quarter being discussed. If any other quantitative data is mentioned outside of Tables 2 and 3, the appropriate Table will be pointed out.*

Story of the Transmission of Confirmed Cases Throughout Sierra Leone

Map of May 20th – May 31st, 2014

The information provided by the SLSR's during this timeframe is very generic and non-specific. The outbreak was just being recognized in this area a few months prior and it may be assumed that there was not reliable or ongoing information and data being distributed at this time. However, a total of 101 confirmed cases did occur during this quarter: 54 in Kailahun or 53.47% of the total confirmed cases within this quarter, 37 in Kenema (36.63%), 3 in Port Loko (2.97%), 3 in Bo (2.97%), 2 in Western Area Urban (1.98%), 1 in Moyamba (0.99%), and 1 in Bombali (0.99%).

As previously mentioned, April of 2014 marked the official start of the outbreak in Sierra Leone. However, the situation reports do not explain the exact mode of which the infection entered the country. The village of Meliandou in Gue´cke´dou Prefecture, Guinea was home to patient zero, the young boy who is thought to have contracted the virus from a fruit bat nest (Gatherer 2014). Guinea is a neighboring country of Sierra Leone and Gue'cke'dou Prefecture is located approximately 67km (41 miles) from the district of Kailahun as seen in Figure 3 (Google Maps 2018). Kailahun experienced over 50% of the confirmed cases during this timeframe. Based on this information, it might potentially be assumed that human movement from Guinea into Kailahun may have been the mode of transmission of the EVD into Sierra Leone. In

addition, Kenema experienced over 36% of the confirmed cases during this timeframe. As seen in Figure 1, Kenema shares its southwest border with Kailahun (The Ministry of Local Government and Rural Development 2015). The district of Bo experienced only 2.97% of the confirmed cases during this timeframe and since Bo shares a border with Kenema it might be assumed that human movement into Bo from Kenama caused the chain of transmission. Thus, human movement occurred from Gue´cke´dou Prefecture, Guinea into Kailahun, Kailahun into Kenema, and Kenema into Bo. As for the other four districts that experienced confirmed cases, they more than likely had human movement from either Kailahun, Kenema, or Bo enter their regions which caused confirmed cases.

It is important to note that the WHO Situation Reports were not used for the results of this quarter. The reason is because the single report from August 29th, 2014 did not provide any information regarding confirmed cases per district nor did it give any highlight summary for Sierra Leone.

Map of June 1st – August 31st, 2014

During this quarter, a total of 1,004 confirmed cases occurred in 13 of the 14 districts within the country. That is an increase of 903 confirmed cases compared to the previous quarter. Both Kailahun and Kenema expressed the highest jump in confirmed cases. The district of Kailahun witnessed an increase of 361 patients from the previous quarter or a 668.52% increase in confirmed cases with a total of 415 confirmed cases within this quarter. Kenema witnessed an increase of 282 patients compared to the previous quarter or a 762.16% increase in confirmed cases with a total of 319 confirmed cases within this quarter. Both of these districts combined had over 73% of the confirmed cases of all the districts during this quarter. This is a substantial jump for both districts. The districts of Port Loko with 66 cases (6.57%), Western Area Urban

with 49 cases (4.88%), Bo with 47 cases (4.86%), and Bombali with 43 cases (4.28%) also witnessed a substantial jump making up almost 21% of the confirmed cases during this quarter. In addition, this districts of Western Area Rural with 28 cases (2.79%), Tonkolili with 16 cases (1.59%), Pujehun with 7 cases (0.7%), Kono with 4 cases (0.4%), Kambia with 1 case (0.1%), and Bonthe with 1 case (0.1%) experienced their first confirmed cases of the EVD and made up almost 6% of the confirmed cases during this quarter. The only district that did not have any confirmed cases of the EVD during both May 20th-31st time period and the quarter of June 1st – August 31st, 2014 was that of Koinadugu district.

Like the previous quarter, neither the SLSR's nor the WHO Situation Reports gave any substantial summary highlights that gave an accurate idea of how the infection spread throughout the country. Through speculation, human movement is more than likely the cause of the spread of confirmed cases in all of the districts infected. As seen in the quarterly map in Figure 7, the highest concentration of confirmed cases is in the original two districts that were more than likely infected via human movement spillover from Guinea, where the outbreak began, in the previous quarter. This is probably why both Kailahun and Kenema witnessed such a significant increase in confirmed cases because both districts had more time for the infection to spread within, through and out of the districts. The map shows that the rest of the country, aside from the district of Koinadugu, was more uniform when it came to confirmed cases. A specific look at the actual data did show there was significant increase in Bombali, Port Loko, Bo, and Western Area Urban. Again, these districts had already been minimally compromised during the first quarter of the outbreak, but the districts still had substantial time to gain confirmed cases of infection which is more than likely the cause of the increase.

Map of September 1st – November 30th, 2014

The quarter of September – November of 2014 expresses the highest confirmed cases in Sierra Leone throughout the entire EVD outbreak. A total of 4,876 confirmed cases are seen in all the districts with Western Area Urban having the highest by expressing 25.51% or 1,244 of the cases during this quarter. Aside from the district of Western Area Urban, the districts of Port Loko, Western Area Rural, and Bombali witnessed the highest confirmed cases at 820 cases or 16.82%, 810 cases or 16.61%, and 785 cases or 16.10% respectively. Unfortunately, Koinadugu finally experienced its first EVD infections with 84 confirmed cases (1.72%). The remaining districts of Kono (2.83%), Kambia (1.72%), Tonkolili (7.32%), Pujehun (0.49%), Bo (4.29%), Bonthe (0.04%), and Moyamba (3.10%) make up the remainder of the districts that witnessed an increase in confirmed cases. On the other hand, both Kailahun and Kenema, the two districts that have previously been on a significant rise in the previous quarters, are the only two districts to show a decrease in the number of confirmed cases. Kailahun witnessed a 77.59% decrease with only 93 confirmed cases or 1.91% of the overall confirmed cases during this quarter. Kenema witnessed a 56.74% decrease with 138 confirmed cases or 2.83% of the overall confirmed cases during this quarter.

According to the WHO Situation Reports during this quarter, Sierra Leone was lacking beds countrywide. This was an ongoing issue as at the end of September the country had 323 beds for confirmed cases but needed 532 more. By the end of the quarter, roughly 350 beds were being utilized but the healthcare facilities needed over 1,200 more beds to accommodate those infected. This posed a significant issue in areas that did not have ample bed space. As previously mentioned, human movement on any scale is detrimental during outbreaks of this nature. Anyone infected with the EVD is likely to become disoriented and wander off which may put them into a situation that has them encountering individuals who are not infected. This

could have potentially increased the chain of transmission which more than likely became uncontrollable given the right circumstance.

Another interesting trend the WHO Situation Reports included was the number of HCWs becoming infected. As previously mentioned, HCW preparedness and education, or lack thereof, has the potential to exacerbate transmission rates. At the beginning of the quarter 71 HCWs were confirmed infected and by the end of the quarter, 132 HCWs were confirmed infected. That is an increase of 61 HCWs or an 85.92% increase. That is substantial given the circumstances of this outbreak. The case of Emory University Hospital, who had been prepared and educated for the EVD, and the country of Nigeria, that has an extensive healthcare system, proved that preparedness could substantially lower transmission rates (Woods 2016) (Ohuabunwo, et al. 2016). Clearly, Sierra Leone's HCW's were not prepared for this type of outbreak with that type of significant increase in confirmed cases over the course of the quarter.

Throughout the course of the quarter, the WHO Situation Reports stated that conditions nationally based on confirmed cases within the county were deteriorating at a steady scale. In addition, Freetown was experiencing significantly high confirmed cases throughout the entirety of the quarter. As previously mentioned, high populated urban areas tend to become incubators of infection and the spread of infection during outbreaks. This is due to the vast amount of contact and proximity people in urban areas have with one another (Alyanak 2017). By the end of the quarter Western Area Urban had significantly higher confirmed cases compared to any other district. Furthermore, according to the WHO Situation Reports, the districts of Port Loko and Bombali were the worst drivers of widespread transmission. This was because there were not enough beds which prevented infected individuals from going into isolation. Instead, they were being turned away because beds were unavailable. Through human movement, those

people left the facilities and traveled to other locations within those districts further driving the chain of transmissions outside of Western Urban Area. Based on the quarterly map in Figure 8, the area of Freetown (Western Urban Area) and the neighboring district of Port Loko and Bombali expressed saw higher confirmed cases.

During the end of this quarter, the districts of Kenema and Kailahun were showing a decrease in confirmed cases which is significant considering these districts potentially began the major line of transmission from Guinea (Gatherer 2014). According to the WHO Situation Reports, Kenema and Kailahun had significant response efforts that isolated and tracked chains of transmission with the goal of breaking the chains through isolation of those infected. The WHO believes this was the main reason behind the transmission slowing down within these districts.

Map of December 1st, 2014 – February 28th, 2015

The quarter of December 2014 through Februart 2015 showed a decline in all districts. Again, Western Area Urban showed the highest confirmed cases at 35.98% or 857 cases. Western Area Urban's neighboring districts of Port Loko and Western Area Rural saw the second and third highest confirmed cases at 22% or 524 cases for Port Loko and 13.10% or 312 cases for Western Area Rural. These three districts made up over 70% of the confirmed cases during this quarter in Sierra Leone. The districts of Bombali (8.44%), Kono (6.76%), Kambia (4.49%), Tonkolil (3.40%), Bo (2.31%), Moyamba (1.97%), Koinadugu (0.97%), Kenema (0.38%), Kailahun (0.13%), and Bonthe (0.08%) made up the rest of the confirmed cases during this quarter. Fortunately, the district of Pujehun had zero confirmed cases and is the first district to have had no incidences since the outbreak occurred in the district.

According to the WHO Situation Reports, conditions at the beginning of this quarter were difficult within Sierra Leone as it was coming out of the worst quarter (September – November 2014) since the outbreak began. As of the week of December 3rd Situation Report from the WHO, Sierra Leone had more confirmed cases compared to Guinea and Liberia combined by this point. Western Area Urban was continuing to be the hardest struck. This is visually evident in the quarterly map of Figure 9, as Western Area Urban is the only district to be in the yellow coloration of 30.01% - 45.00% level. However, response to the outbreak was starting to make a difference. Although there were some isolated instances of transmission increases, for the most part, a shift in how the outbreak was progressing became somewhat evident, because by the end of December, things began to significantly slow down when it came to the increases in confirmed cases.

Although confirmed cases were slowing down, some things were not on the decline. The number of beds needed were continuously on the rise and became extremely problematic when it came to tracking and breaking the chains of transmission. Coming into this quarter, 900 beds were needed but by mid-December, over 1,400 beds were needed. Even though the quarter showed an overall decrease in confirmed cases, according to the WHO Situation Report, the week of December 17th showed the highest number of weekly confirmed cases throughout the entire outbreak of EVD included those in other countries. This prompted the United Nations, the WHO, and the Government of Sierra Leone to enable the Western Area Surge (WAS). WAS targeted the hardest hit areas, such as Freetown, and began to increase the number of beds in the healthcare facilities in order to ensure that confirmed cases were being isolated and received appropriate treatments. WAS also attempted to provide rapid response teams to be set up within each district to address new confirmed cases as swiftly as possible. WAS was implemented in

hopes to decrease the momentum of the chains of transmission. By isolated confirmed cases, healthcare facilities were able to decrease the amount of exposure non-infected individuals had with those infected. This tactic seemed to be working as chains of transmission were being severed, confirmed cases were being discovered faster which allowed for earlier isolation of those infected, and fewer beds were needed going into January. This trend continued throughout the rest of the quarter and by the end of the quarter, enough beds were being supplied to care for the confirmed cases and more healthcare facilities were being opened in order to help combat the outbreak. In addition, samples that were taken to either confirm or deny infection of those suspected and probable cases were taking 1 to 4 days to be tested. This was considerable as in previous quarters it was taking an unknown number of days to weeks before confirmation was given to facilities. This is significant as the quicker the facility was able to confirm a case of EVD, the confirmed cases were put into isolation, chains of transmission were being broken, and the patients were being treated promptly. This could have prevented the spread of the EVD through human movement and it could have also prevented new chains of transmission from forming.

Unfortunately, while WAS was working when it came to breaking the chain of transmission that was occurring throughout the districts via human movement, HCWs were seeing a rise in the number of confirmed cases. At the beginning of the quarter, 138 HCWs were confirmed infected but by the end of the quarter, 295 HCWs were confirmed infected. This was an increase of 157 HCWs or a 113.77% increase. Regrettably, even though the WAS was helping the nation, HCWs and their lack of preparedness and education when it came to the EVD more than likely put them in situations that they became infected. Thankfully, with the WAS in place, it may be assumed that if a HCW became infected, they were likely isolated very quickly

due to the increase in bed availability near the end of the quarter to prevent further chains of transmission from forming within the healthcare facilities. This quarter in its entirety showed a significant decrease in confirmed cases compared to the previous quarter. By the end of the quarter only the western districts were seeing the most confirmed cases as seen in Figure 9. Transmission was declining rapidly, and it seemed that the peak of the outbreak was beginning to pass.

Map of March 1st – May 31st, 2015

In the quarter of March – May 2015, there was a significant decrease from the previous quarter of confirmed cases. In total between all districts, 271 confirmed cases were witnessed compared to the previous quarter's total of 2,382, which is a difference of 2,111 confirmed cases or a decrease of 88.62%. Again, Western Area Urban expressed the highest confirmed cases at 115 cases or 42.44% of the confirmed cases within this quarter. Yet again, both Port Loko and Kambia had the second and third highest confirmed cases with Port Loko witnessing 58 cases or 21.40% of the total confirmed and Kambie amounting to 54 cases or 19.93% of the total confirmed throughout this quarter. These three districts made up over 83% of the confirmed cases throughout Sierra Leone during this quarter. In addition, Western Area Rural (9.23%), Bombali (5.17%), Moyamba (0.74%), Tonkolili (0.37%), Koinadugu (0.37%), and Kono (0.37%) made up the rest of the districts that witnessed confirmed cases. However, 5 districts (Kalihun, Kenema, Bo, Pujehun and Bonthe) had zero confirmed cases this quarter which is the highest number of districts since the second quarter of the outbreak (June – August 2014) to have zero confirmed.

According to the WHO Situation Reports for this quarter, during the entirety of the quarter all healthcare facilities had ample amount of beds for incoming patients. In addition,

going into this quarter things began to stabilize. The number of incidences of chains of transmission, confirmed, suspected, and probable cases began to decrease sharply. Over 92% of the transmission chains that were being discovered were investigated within 24 hours of confirmed cases. A national Ebola Alert Hotline was put into place which allowed people to call in and report potential cases, bodies that needed to be discarded safely, or for information regarding where to go if they suspect infection. By the end of March there was a steady decline in confirmed cases and healthcare facilities were beginning to operate more smoothly. Freetown and the Western Area Urban district along with its neighboring districts still witnessed confirmed cases. As seen in the quarterly map in Figure 10, Western Area Urban, Port Loko, and Kambia seemed to be the hub of most confirmed cases. The quantitative data for this quarter confirms this as well.

During this quarter, healthcare facilities began to bounce back with only 8 HCWs becoming confirmed cases which is a significant decrease from previous quarters. This is important as the WHO Situation Report for the week of May 27th, 2014 announced that healthcare facilities were implementing more vigilant precautions, situations within facilities were less chaotic, and fewer individuals were coming in to be tested for EVD. By the end of the quarter, EVD testing was at its fastest, because once an individual was tested, it took less than a day for the results to come in. Of those being tested, less than 1% were coming back positive for the virus. This was significant as it exhibited the decline in confirmed cases and the transmission of the virus seemed to be slowing down tremendously.

Map of June 1st – August 31st, 2015

In the quarter of June – August 2015, only four districts had confirmed cases. Port Loko had the most with 28 cases or 35.90% of the total cases for this quarter. Both Western Area

Urban and Kambia had 24 cases each (30.77% each). Lastly, Tonkolili had only 2 confirmed cases (2.56%) for the quarter.

According to the WHO Situation Reports, it was discovered Kambia seemed to have communication issues with response teams. Residents, healthcare facilities, and HCWs were not understanding how to correctly respond to the outbreak. When members from response teams were going in to help, it was stated that the facilities were giving them resistance. By speculation, this may be a result of healthcare facilities and HCWs not fully understanding EVD. If the response team practices of treatment or isolation for those infected with the EVD differ from the protocols of the facility, the HCWs and the facility may not have correctly responded to those changes. It may not be because they are being difficult but instead, these facilities may be finding it hard to change their protocols, or understand what isolation exactly means. However, overall HCWs in general throughout this quarter seem to have decreased substantially. Only 3 HCWs became infected during this timeframe. That is 5 fewer than the previous quarter which signifies that while Kambia may be struggling, the other districts and the country as a whole are responding to the virus more diligently and more strongly than previous quarters.

As the quarter progressed it became evident that most chains of transmission were coming from Freetown, or the Western Area Urban district. This is visually seen in the map of the quarter, Figure 11, as Western Area Urban and Port Loko have the highest concentrations with both of the being a shade of yellow or 30.01%-45.00% confirmed. Human movement out of Freetown and into other districts was responsible for the transmission of the virus to move such great distances. The outcome of that human movement was substantial as the district of Tonkolili had a single individual that tested positive for the virus in a private hospital. The individual was not isolated for over 2 days before the facility realized the individual was

infected. This person's chain of transmission had begun in Freetown where they then traveled into Tonkolili where they had become ill. Between Freetown, their settled location in Tonkolili, and the healthcare facility, that single individual had created a potential chain of transmission of over 600 people. Those 600 people from Tonkolili were being monitored and put under voluntary isolation in their homes in hopes to break the chain of transmission in order to prevent the spread of the virus if any of them became sick. This shows the power of human movement and how one chain of transmission can cause a cascading event in which hundreds of other people are put at risk. This event reflects the magnitude of the outbreak and why it spread so quickly and ferociously throughout Sierra Leone.

Map of September 1st – November 30th, 2015

During the quarter of September – November 2015, only 2 districts saw confirmed cases. The district of Kambia had 5 confirmed cases or 83.33% of the total confirmed within this quarter and Bombali only had 1 case (16.67%). As seen in the quarterly map, Figure 12, this marks the first time that Freetown and the Western Area Urban had zero confirmed cases since the start of the outbreak in Sierra Leone. This is significant as most chains of transmission were coming out of this area. For this district to show zero confirmed cases, chains of transmission seemed to have stopped, which could have potentially been a very large driving force for the outbreak overall. By the end of this quarter Sierra Leone had not experienced any new confirmed cases. The only countries that were experiencing confirmed cases during this time was Guinea and Liberia. However, Liberia's outbreak had substantially declined much like Sierra Leone's.

According to the WHO Situation Reports, the beginning of this quarter marked the initiation of the Ebola ça suffit! ring vaccination Phase 3 efficacy trial of the VSV-EBOV

vaccine. This vaccine had been available to Guinea since March of 2015. However, at the beginning of September, the vaccine became available to both Liberia and Sierra Leone. The ring vaccine method is used by finding a confirmed case of the pathogen and doing heavy vaccination within a specific radius of the confirmed case. Anyone exposed to the patient receives the vaccine in hopes of preventing the spread of the virus (CDC 2017a). Only individuals who qualify can be vaccinated. The individual must be 18 years old, have never been infected with EVD in the past, is not pregnant, is free of any immunodeficiency conditions such as HIV/AIDS, and is not chronically ill (WHO 2015a). Although during the most intense months it is unlikely that the vaccine would have been able to contain the outbreak, during this quarter it was used in hopes of stopping the few chains of transmissions that were still active (Kucharski et al. 2016). It was unknown during this time in the outbreak if the vaccine was working. However, since only 2 districts witnessed confirmed cases throughout the entirety of the quarter, it may have helped curb the outbreak.

For all the confirmed cases in both Kambia and Bombali, the origin of transmission was unknown. The reason for this is because the patients did not become confirmed cases until after they died and because of this response teams could not track the origin of transmission. However, response teams were able to track chains of transmission for the people who had come into contact with the confirmed cases. These individuals were put into isolation for a 21-day time period to prevent further spread of the virus. In addition, no HCWs became infected during this quarter.

Map of December 1st, 2015 – February 29th, 2016

During the quarter of December 2015 – February 2016, a significant decrease of confirmed cases was witnessed. Only 2 confirmed cases were discovered with 100% of them

being in the district of Tonkolili. This is visually seen in Figure 13 as Tonkolili is the only district to express any type confirmed cases with its bright red coloration.

According to the WHO Situation Reports, the beginning of the quarter marked the WHO and Sierra Leone's Ministry of Health and Sanitations efforts to begin aiding the survivors of the outbreak. They developed a framework to combat the many health issues and mental health dilemmas many survivors, HCWs, and the family and friends of both survivors and deceased experience because of the EVD outbreak. With fewer and fewer confirmed cases and only few chains of transmissions present, these agencies were able to begin focusing on the rebuilding of the society as the virus began to diminish (WHO 2016c).

This also marked a time in which Sierra Leone went into a 90-day period of surveillance. The country had not experienced any new confirmed cases since mid-September. However, 68 days into the 90-day period of surveillance, a deceased 22-year-old female tested positive for EVD in the Tonkolili district. Prior to her death she had been traveling while she was symptomatic and infectious from Port Loko, through Kambia, and into Bombali before arriving in Tonkolili and dying. Response teams immediately jumped in to discover her chain of transmission. Over 150 people were found within her chain of transmission but only 50 of them were thought to be at considerable risk of becoming infected. Those 50 individuals were vaccinated as a precaution. In addition, her aunt became ill and tested positive for EVD. It is unknown if her aunt had been vaccinated prior to falling ill. However, under isolation, her aunt was transported from Tonkolili to the Western Area Urban district and was put in isolation at a treatment center in Freetown. These were the only two confirmed cases during this quarter.

Map of March 1st – May 31st, 2016

As seen in Figure 14, the quarter of March – May 2016 witnessed zero confirmed cases. The EVD outbreak had ended. The Public Health Emergency of International Concern officially called the West African EVD Outbreak of 2014 as being over on March 29th, 2016. The WHO Situation Reports stated that as the outbreak was officially being named as over, over 2,600 survivors were being assessed for general health, mental health, eye exams, semen screening and counselling services. By April, the WHO Situation Reports began to shift from reporting on EVD to reporting on the Yellow Fever outbreaks and the Zika Virus.

Visual and Qualitative Summary of the Outbreak

The outbreak began relatively slowing and mostly confined to a few districts. Much like when the outbreak began in Guinea in December of 2013, the virus went relatively unnoticed. As seen in Figure 6, Kailahun and Kenema were the hardest hit, but the other districts had minimal confirmed cases. From June to August of 2014, the outbreak began to pick up momentum. More people were becoming infected as more confirmed cases were coming in. Kailahun and Kenema were witnessing more confirmed cases and the virus began to make its way into higher populated areas such as Western Area Urban. By September – November of 2014 things began to deteriorate significantly. In September of 2014, healthcare facilities had no beds and were turning away sick people. These people were being shunned by their communities because they were sick, and when they sought help, help was unavailable. If people were unable to be isolated when they were sick, they were likely interacting with others which potentially increased infection rates and created countless chains of transmission. By October, infection rates were rampant as more and more people became infected. Freetown, Western Area Rural, Bombali, and Port Loko were the hardest hit as seen in Figure 8. By November of 2014, Freetown was the worst hit with over 1,200 confirmed cases and Western

Area Rural also witnessed over 800 confirmed cases. Port Loko and Bombali were also getting hit very hard with the EVD. Over 1,200 beds were needed to isolate those infected. At the time, facilities were still turning people away.

During the quarter of December 2014 – February 2015, the beginning of the quarter conditions started out somewhat difficult as the country was coming out of the hardest hit quarter during the outbreak. However, things were beginning to improve as confirmed cases were decreasing in most districts, WAS was implemented to curb the intensity of the outbreak, and chains of transmission were being broken. By January 2015, things began to level off. The worst of the outbreak was over. As seen in Figure 8, most of the confirmed cases were in the western portion of the country. In those areas, beds were still needed but instead of needing 1,200 beds like in the previous quarter, only 700 needed. By the end of January, zero beds were needed. Puzzlingly, while confirmed cases were dropping significantly, HCWs were becoming infected at alarming rates. However, because beds were no longer needed, as HCWs were becoming ill, they were given isolation as soon as possible. Chains of transmission were being broken and infection rates were decreasing.

By March – May of 2015, as seen in Figure 10, 6 districts had zero confirmed cases with most confirmed cases still being witnessed in the western, more populated areas of Sierra Leone. By April, there was significant decreases in confirmed cases and chains of transmission. Although HCWs were still becoming infected, their infections had dropped dramatically. The outbreak was beginning to taper off. By June – August of 2015, fewer and fewer people were becoming infected. More districts were witnessing zero confirmed cases as seen in Figure 11. Although there was resistance in Kambia at the beginning of the quarter, by the end of the quarter Kambia started to see their confirmed cases decease drastically. The most populated

areas of Port Loko and Western Area Urban seemed to have most of the confirmed cases as seen in Figure 11. More healthcare facilities were being shut down as they were no longer needed.

During the September – November 2015 quarter, as seen in Figure 12, most districts were free of confirmed cases. In addition, only 6 confirmed cases in the districts of Kambia and Bombali were witnessed. The outbreak was almost over. The focus had shifted to repairing the damage the virus and the outbreak had done to communities, societies, families, widowers, children, people, and homes. Recovery frameworks were put into place to help aide this effort as the country began to heal itself. By December 2015 – February 2-16, the last remaining confirmed cases had been identified as seen in Figure 13, and the chains of transmission had been isolated and vaccinated. By March of 2016 the outbreak was officially over as seen in Figure 14. In the end, 3,955 people lost their lives in Sierra Leone and the outbreak affected thousands of other individuals: the survivors, HCWs, caregivers, widowers, orphaned children, and an entire society. In total, 11,301 individuals succumbed to the EVD worldwide (WHO 2016a).

VI. Conclusion

The EVD Outbreak of 2014 ravaged Sierra Leone as the country was not prepared for such a lethal and dynamic viral outbreak. The questions continue to remain: Are urbanized areas more prone to higher infection rates? Will HCWs see high infection rates during the outbreak? Are healthcare facilities within Sierra Leone prepared for such a highly infectious disease? Lastly, does human movement increase infection rates during the outbreak of 2014?

It is obvious within Sierra Leone that urbanized areas witnessed higher infection rates during the outbreak. Between September – November of 2014 Western Area Urban saw 1,244 confirmed cases as seen in Table 2. The second highest confirmed cases throughout the entire outbreak were witnessed in Western Area Urban again during the December 2014 – February 2015 quarter with 857 confirmed cases. Both incidences occurred in the most heavily populated areas of the country, Freetown with over 1 million residents. In addition, although quantitative statistics were not conducted to provide statistical significance, HCWs did see a steady increase in infection rates throughout the outbreak. Through speculation, this is more than likely due to healthcare facilities throughout Sierra Leone being under-funded, under-resourced, and ill-equipped to handle such a massive outbreak. There was not enough beds, sanitation equipment such as gloves to be able to safely care of those infected. Lastly, human movement occurred several times during the outbreak. The introduction of the virus into Sierra Leone was through human movement via Guinea. Chains of transmission were being followed through several districts and intra-city movement was probably the leading cause of increased confirmed cases in Freetown with Western Area Urban.

In addition to the presented questions, the following hypotheses were offered to understand how the EVD made its way through Sierra Leone:

- H_a: It is hypothesized that due to lower poverty levels high urbanization and/or human movement may cause significant infection rates during outbreaks of the EVD.
- H_0: It is hypothesized that due to lower poverty levels high urbanization and/or human movement will not cause significant infection rates during outbreaks of the EVD.

In addition:

- H_a : It is hypothesized that the lack of preparedness, lower education, and/or the insufficient number of HCWs may cause significant infection rates during outbreaks of the EVD.
- H_0 : It is hypothesized that the lack of preparedness, lower education, and/or the insufficient number of HCWs will not cause significant infection rates during outbreaks of the EVD.

As previously stated, high urbanized areas did see significant infection rates. In addition, human movement was proven to have caused a number of chains of transmission, increased infection rates and the introduction of the virus into Sierra Leone. Second, healthcare facilities have issues with being ill-prepared as they lack beds, HCWs were not following the protocols set up by response teams, and people were being turned away due to healthcare facilities inabilities among several other issues. Suffice it to say, it is probable that significant infection rates did occur because of the lack of preparedness healthcare facilities and HCWs expressed during the outbreak.

This study took a comprehensive look into Sierra Leone's journey through the EVD Outbreak of 2015, but Liberia and Guinea also experienced significant infection rates, confirmed

cases, and over 11,000 deaths in association with the outbreak. A comprehensive study of those countries may be chosen in order to understand if the potential factors that may have increased confirmed cases throughout Sierra Leone are the same factors that Liberia and Guinea may have experienced as well. Although a number of entities such as the CDC, the WHO, and OSHA are taking measures to control and prevent other EVD outbreaks in the future, another outbreak will happen (OSHA 2018). It is not a matter of if. It will happen. Some may speculate as to where the Ebolavirus, from fruit bat, or any of its other strains originated, but the natural reservoir of the EVD has never been found and confirmed. It is still out there, and it has the potential to be worse than this latest outbreak. Any and all studies surrounding the EVD Outbreak, how to prevent it, how to control it and how to recovery from it are desperately needed.

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XII. Appendix

Figure 1. Districts of Sierra Leone (The Ministry of Local Government and Rural Development 2015).

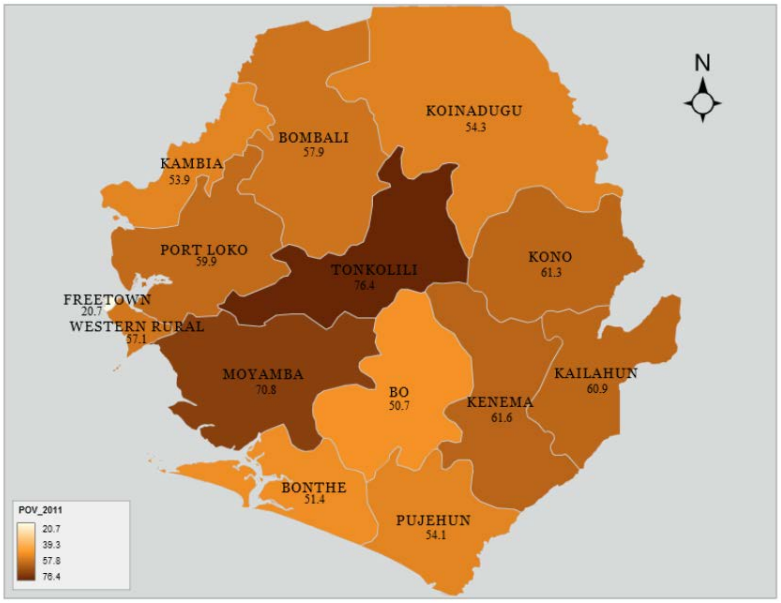

Figure 2. Poverty Headcount by district in 2011 (The World Bank 2013) (SLIHS 2011).

Figure 3. Distance between Gue´cke´dou Prefecture, Guinea and Kaliahun, Sierra Leone (Google Maps 2018).

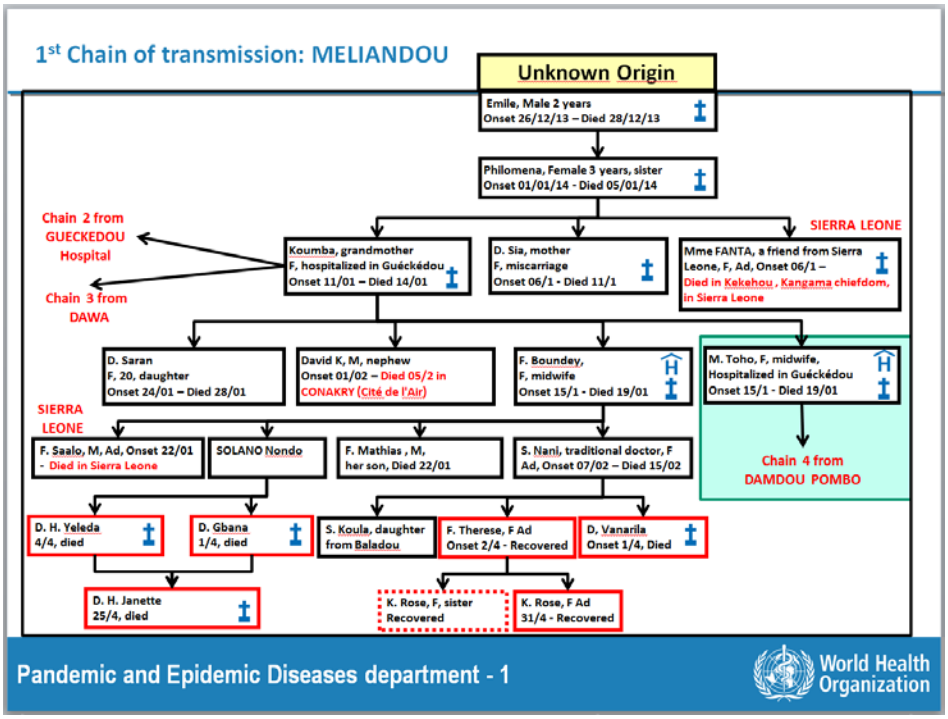

Figure 4. Example of Chains of Transmission (WHO 2018b).

Table 1: National Cumulative summary of Ebola Cases 20 May – 13August 2014

Name of district	District population	Number of cases on 13 August 2014				Cumulative cases as of 20 May - 13 August 2014				Cumulative deaths			CFR
		Non-Case	Suspected	Probable	Confirmed	Cumulative Non-Case	Suspected	Probable	Confirmed	Suspected	Probable	Confirmed	
Kailahun	465,048	5	0	0	11	206	0	32	389	2	32	157	40.4
Kenema	653,013	2	2	1	1	279	3	1	261	1	0	107	41.0
Kono	325,003	0	0	0	0	15	33	1	1	0	0	0	0.0
Kambia	341,690	0	0	0	0	1	0	0	1	0	0	0	0.0
Koinadugu	335,471	0	0	0	0	15	0	0	0	0	0	0	0.0
Bombali	494,139	0	0	0	0	10	1	1	7	0	0	1	14.3
Tonkolili	434,937	0	0	0	0	10	0	0	2	0	0	0	0.0
Port Loko	557,978	0	0	0	0	7	0	1	24	1	1	1	4.2
Pujehun	335,574	0	0	0	0	2	0	0	3	0	0	0	0.0
Bo	654,142	3	0	0	1	59	1	1	23	0	0	2	8.7
Moyamba	278,119	0	0	0	0	12	0	0	5	0	0	3	60.0
Bonthe	168,729	0	0	0	0	0	0	0	1	0	0	0	0.0
Western area urban	1,040,888	2	1	0	2	58	1	1	15	1	1	2	13.3
Western area rural	263,619	1	0	0	0	6	0	0	1	0	0	0	0.0
National	**6,348,350**	**13**	**3**	**1**	**15**	**680**	**39**	**38**	**733**	**5**	**34**	**273**	**37.2**
Total		**13**	**19**			**680**	**810**			**312**			

Reclassification of cases is done on daily basis based on the final classification from the Laboratory. NB: CFR is based on confirmed cases

Figure 5. Table used for quantitative data collection and organization. Red highlighted column was the confirmed cases used for this study (Sierra Leone Ministry of Health and Sanitation 2014).

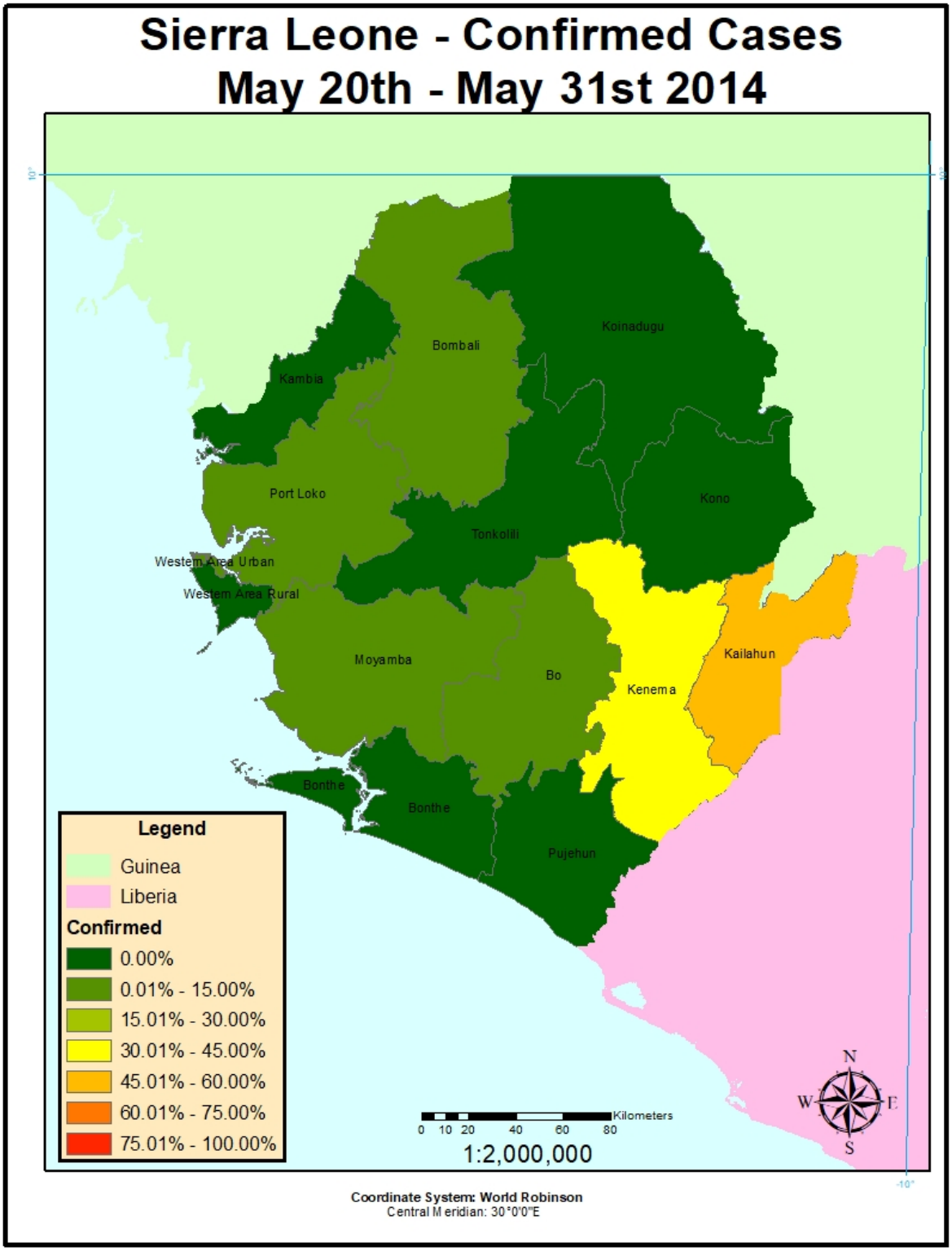

Figure 6. Map of the confirmed cases in percentage form per district within Sierra Leone from May 20th through May 31st, 2014.

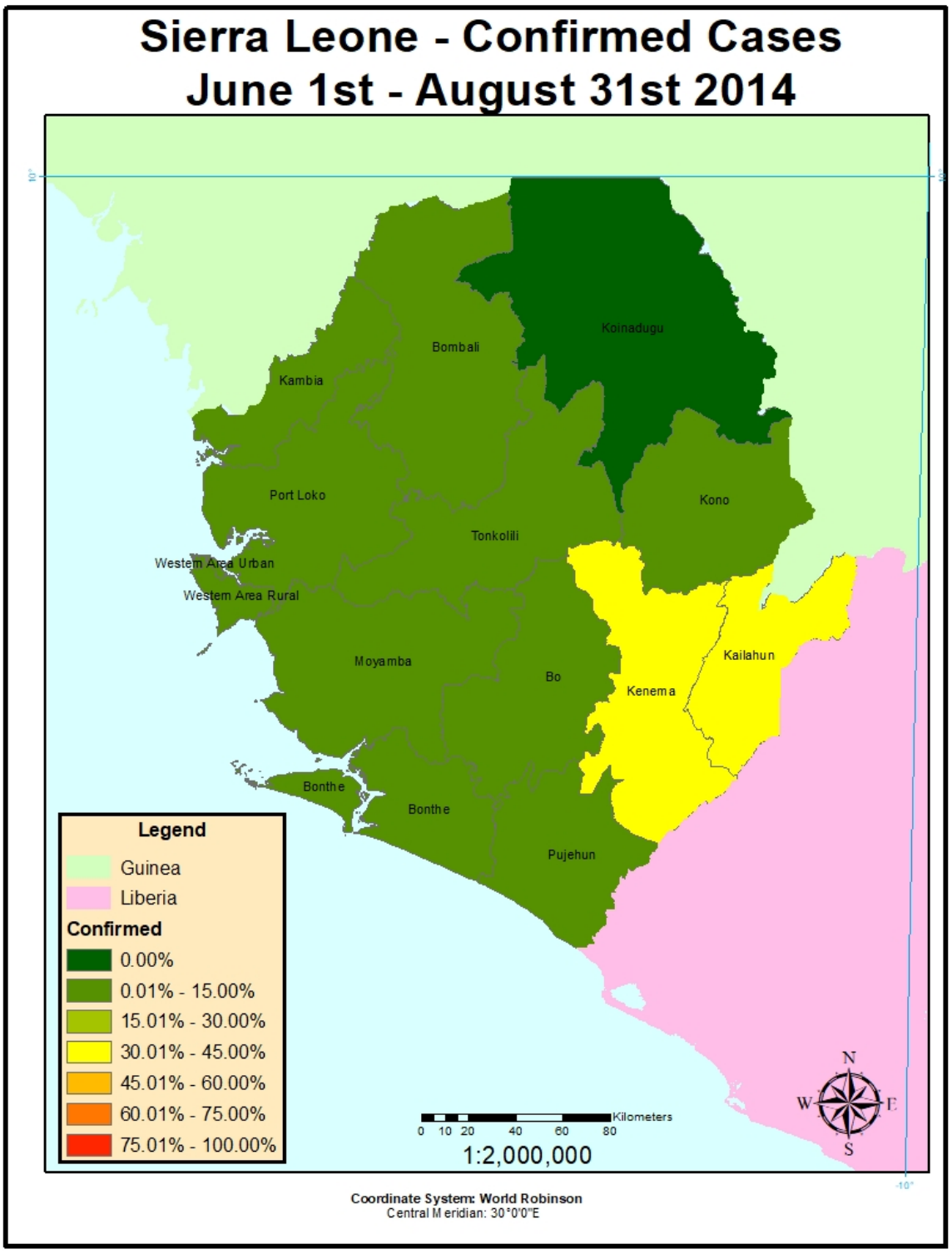

Figure 7. Map of the confirmed cases in percentage form per district within Sierra Leone from June 1st through August 31st, 2014.

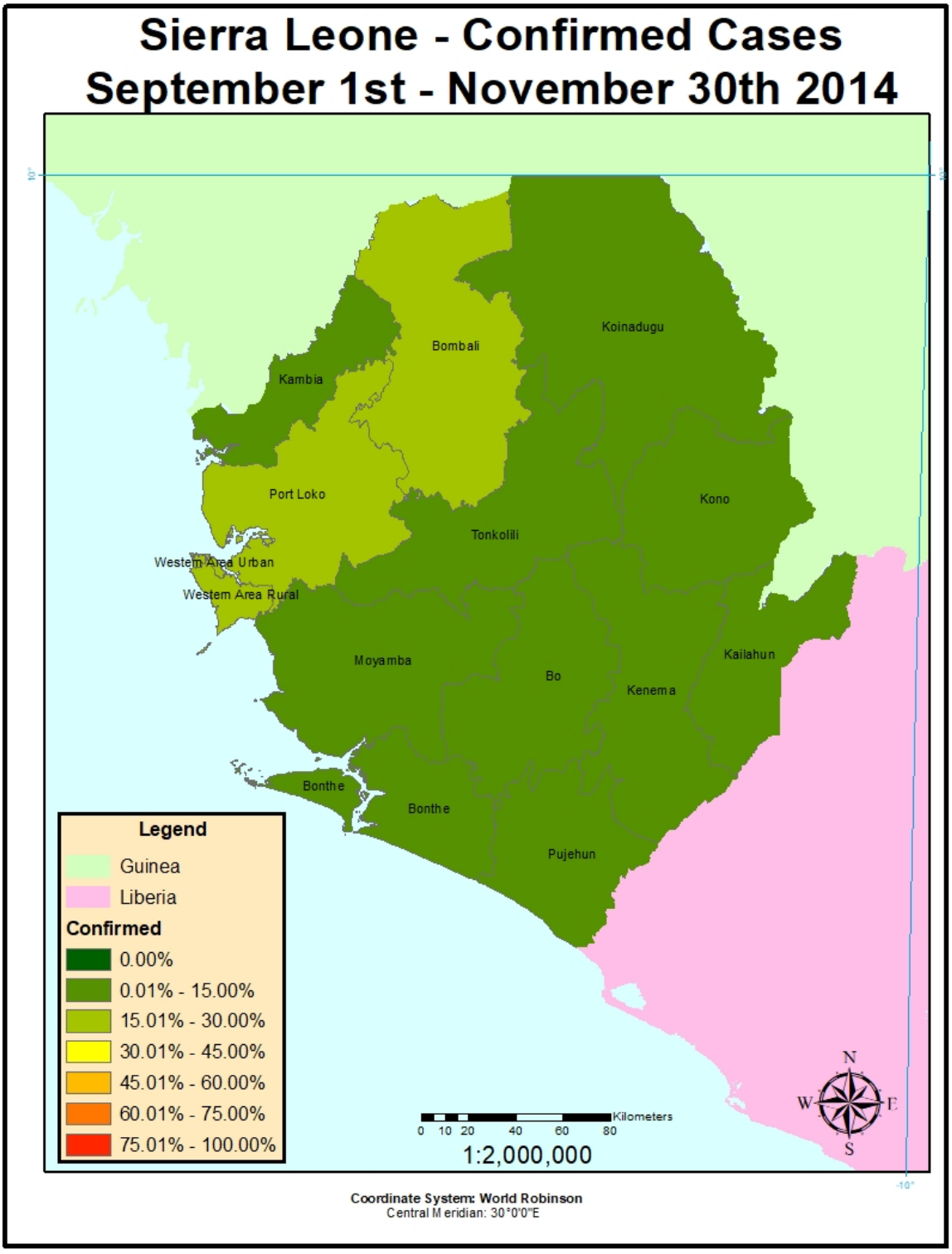

Figure 8. Map of the confirmed cases in percentage form per district within Sierra Leone from September 1st through November 30th, 2014.

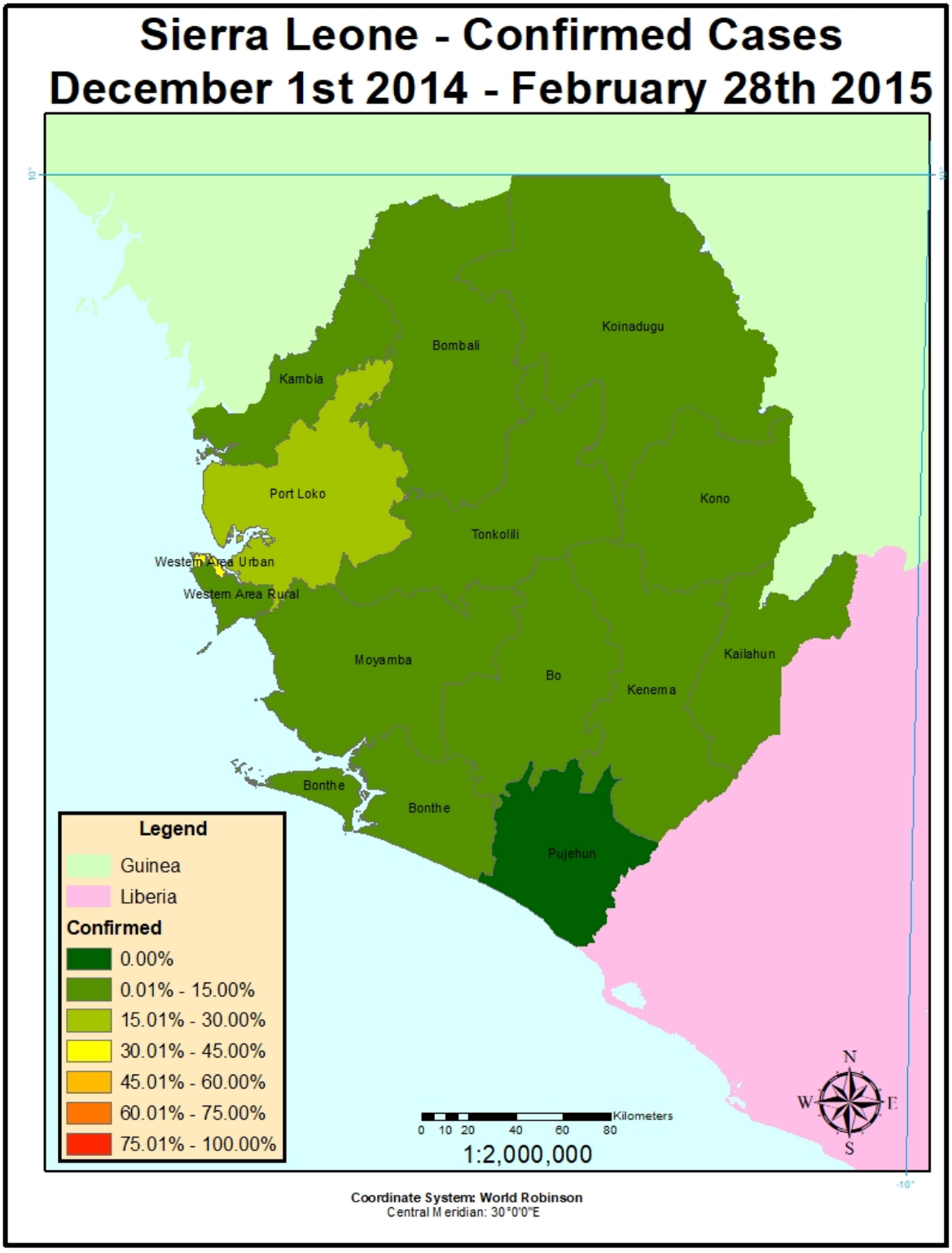

Figure 9. Map of the confirmed cases in percentage form per district within Sierra Leone from December 1st, 2014 through February 28th, 2015.

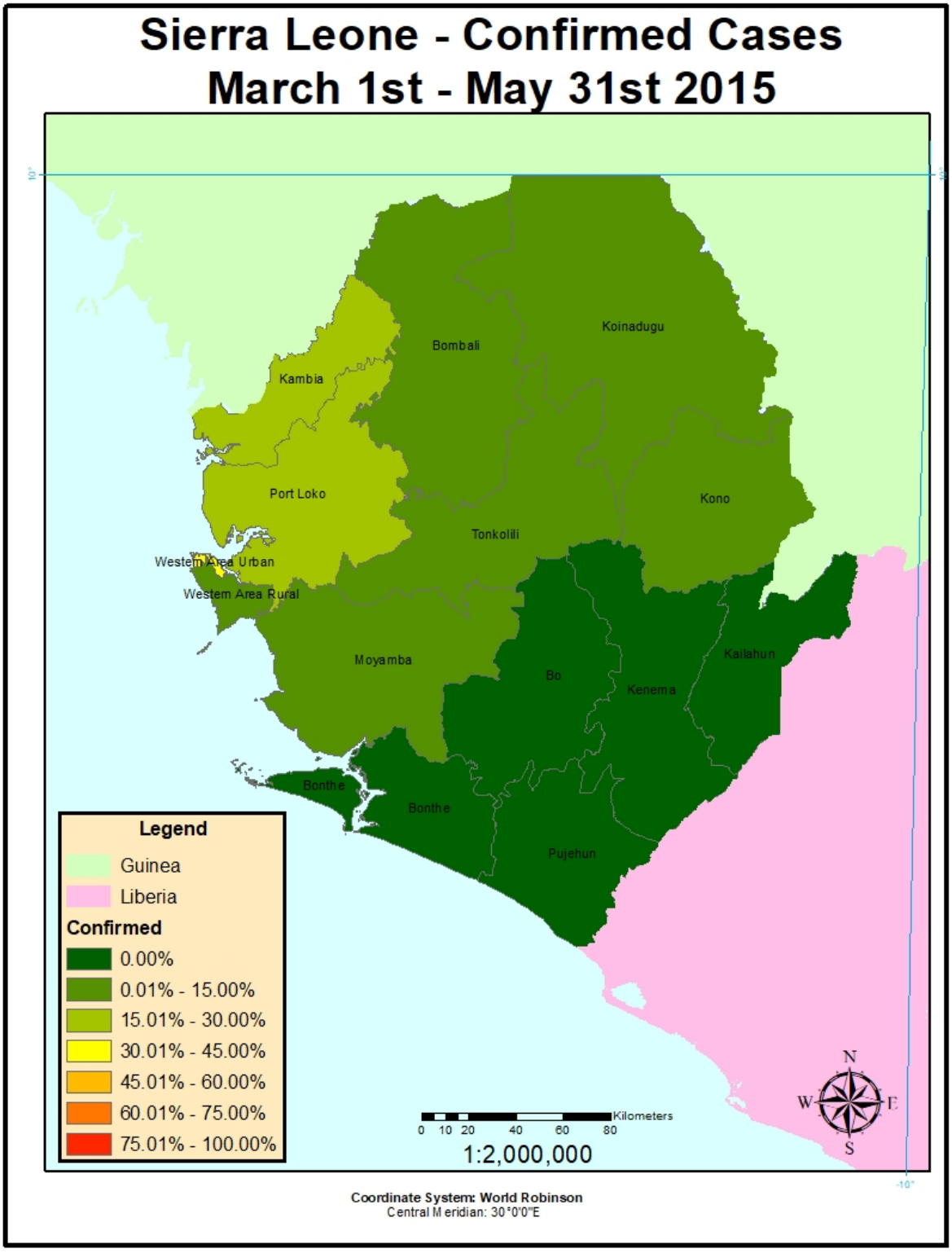

Figure 10. Map of the confirmed cases in percentage form per district within Sierra Leone from March 1st through May 31st, 2015.

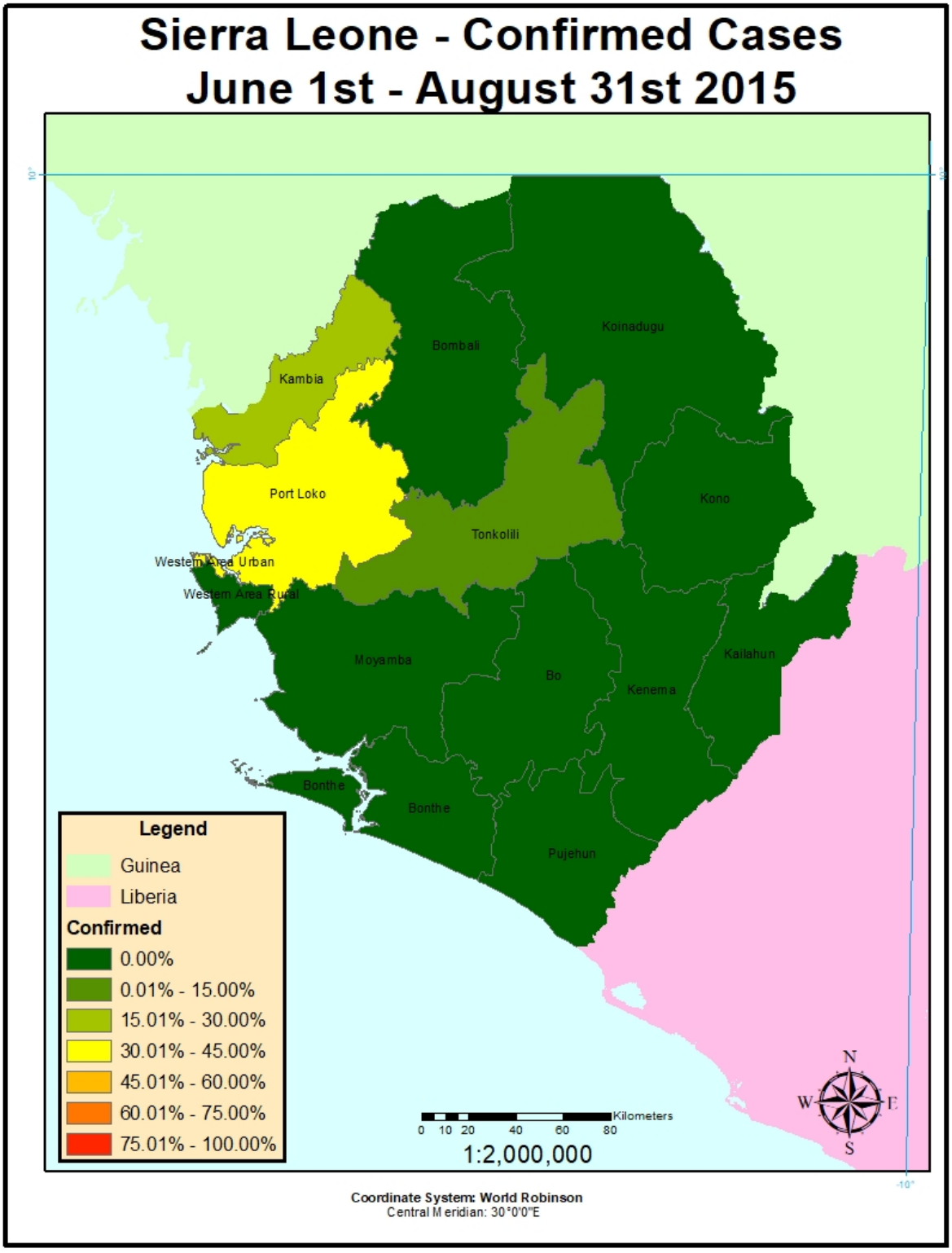

Figure 11. Map of the confirmed cases in percentage form per district within Sierra Leone from June 1st through August 31st, 2015.

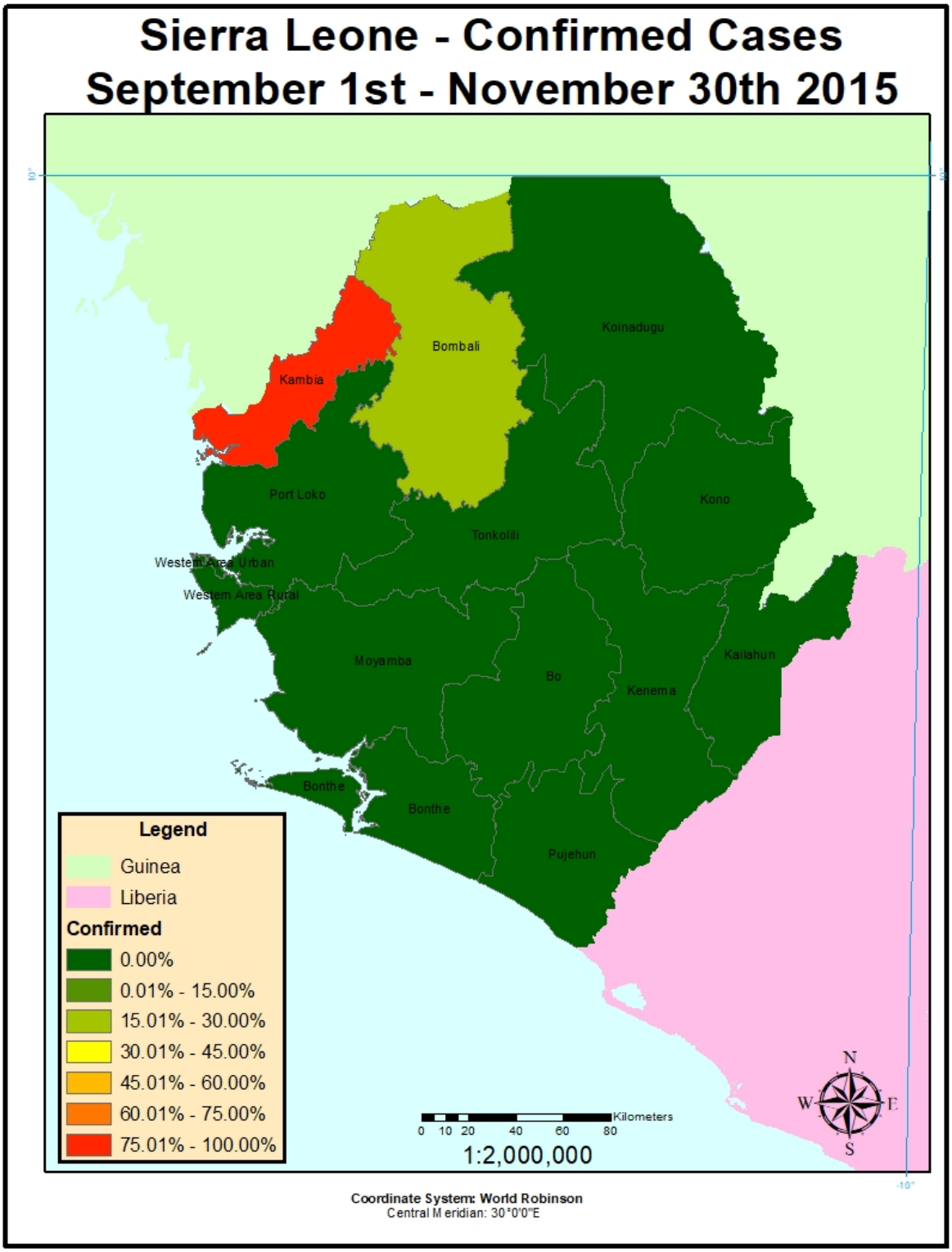

Figure 12. Map of the confirmed cases in percentage form per district within Sierra Leone from September 1st through November 30th, 2015.

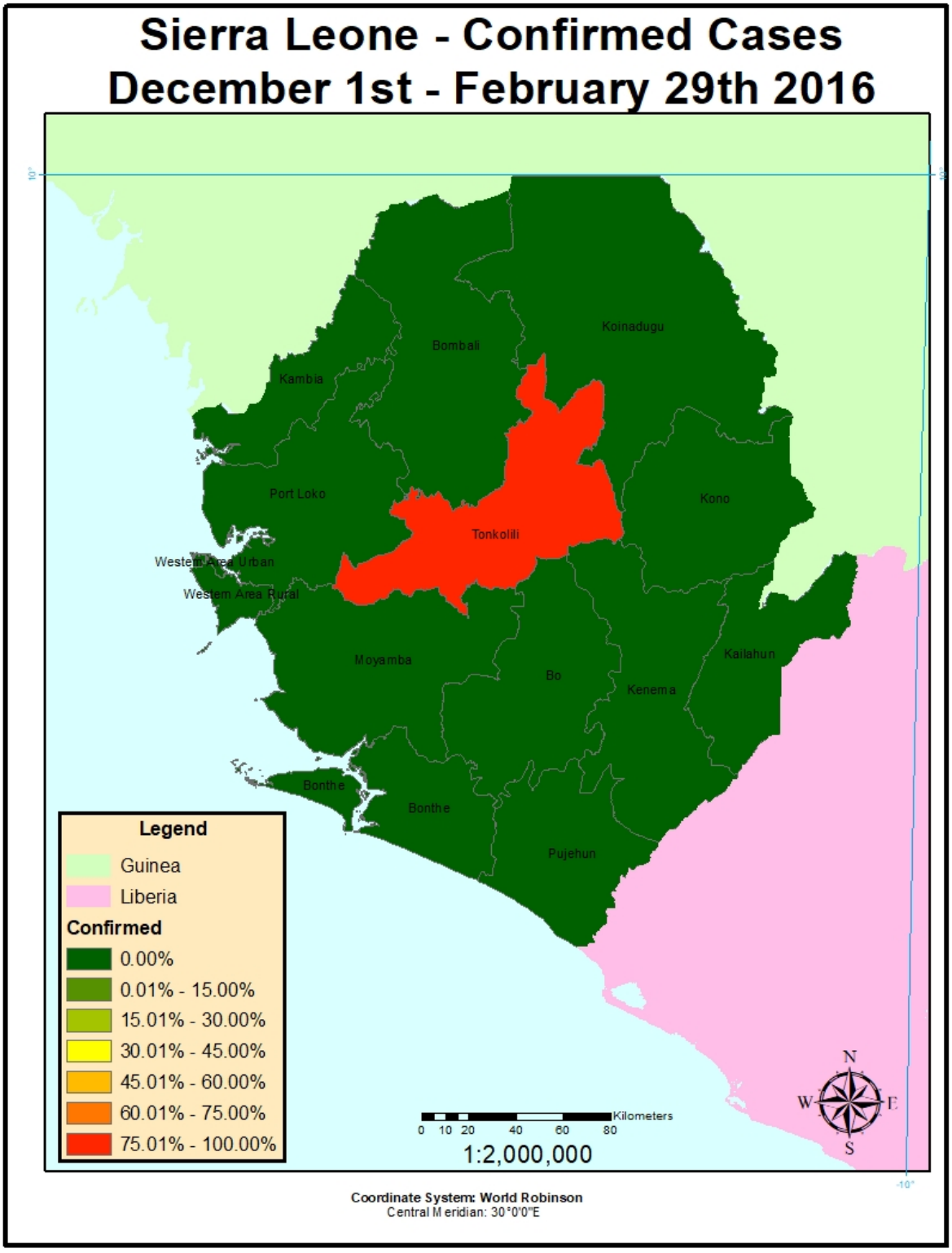

Figure 13. Map of the confirmed cases in percentage form per district within Sierra Leone from December 1st, 2015 through February 29th, 2016.

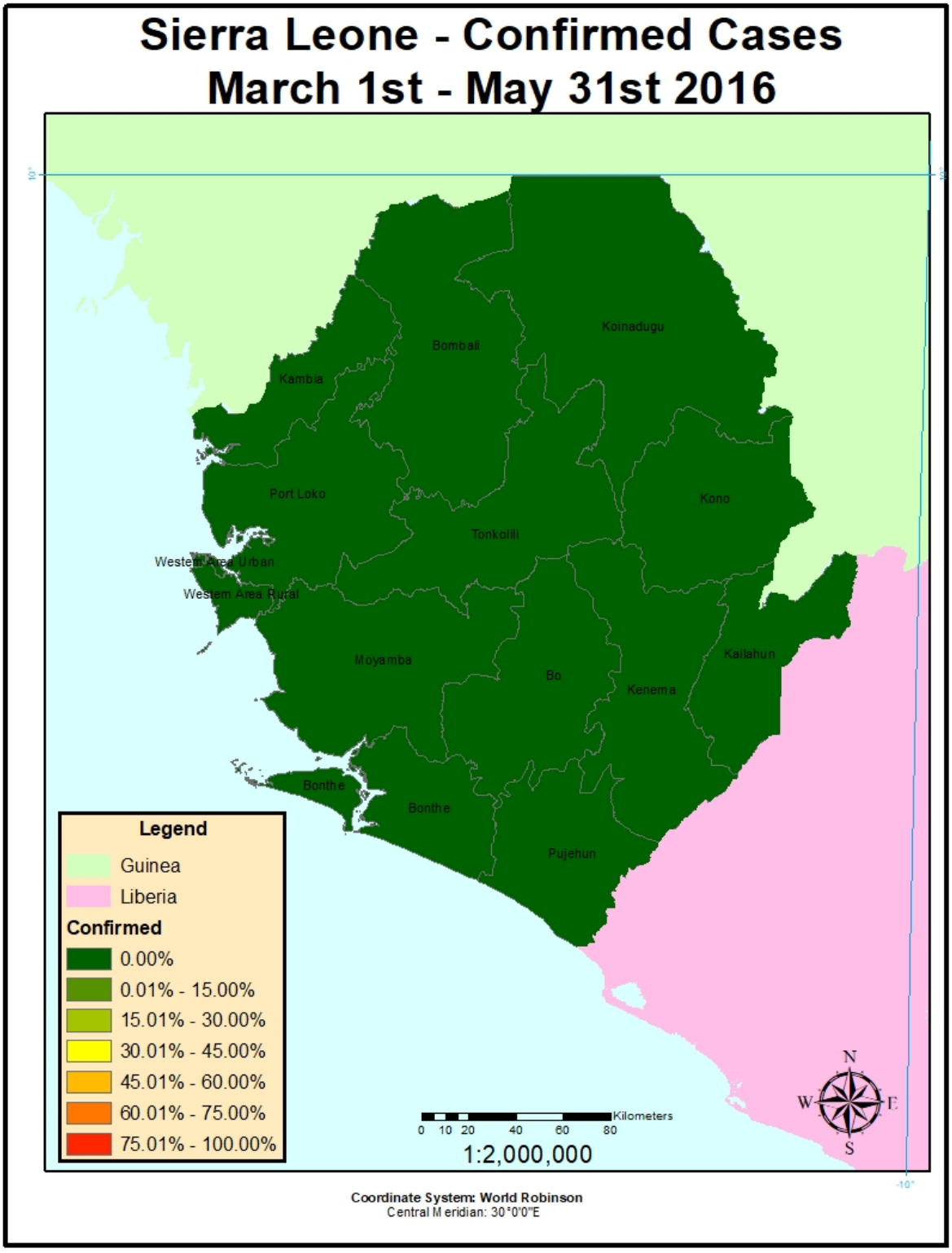

Figure 14. Map of the confirmed cases in percentage form per district within Sierra Leone from March 1st through May 31st, 2016.

Region	*Population*
Kailahun	526,379
Kenema	609,891
Kono	506,100
Kambia	345,474
Koinadugu	409,372
Bombali	606,544
Tonkolili	531,435
Port Loko	615,376
Pujehun	346,461
Bo	575,478
Moyamba	318,588
Bonthe	200,781
Western Area Urban	1,055,964
Western Area Rural	444,270
Totals	7,092,113

Table 1. Population by Districts of Sierra Leone (Sierra Leone Census 2015).

Region	May 20 - May 31 (2014)	June-Aug 2014	Sept-Nov 2014	Dec (2014) - Feb (2015)	March-May 2015	June-Aug 2015	Sept-Nov 2015	Dec (2015) - Feb (2016)	March-May 2016
Kailahun	54	415	93	3	0	0	0	0	0
Kenema	37	319	138	9	0	0	0	0	0
Kono	0	4	84	161	1	0	0	0	0
Kambia	0	1	75	107	54	24	5	0	0
Koinadugu	0	0	84	23	1	0	0	0	0
Bombali	1	43	785	201	14	0	1	0	0
Tonkolili	0	16	357	81	1	2	0	2	0
Port Loko	3	66	820	524	58	28	0	0	0
Pujehun	0	7	24	0	0	0	0	0	0
Bo	3	47	209	55	0	0	0	0	0
Moyamba	1	8	151	47	2	0	0	0	0
Bonthe	0	1	2	2	0	0	0	0	0
Western Area Urban	2	49	1244	857	115	24	0	0	0
Western Area Rural	0	28	810	312	25	0	0	0	0
Totals	101	1004	4876	2382	271	78	6	2	0
All Total	8720								

Table 2. Number of confirmed cases per district per quarter within Sierra Leone.

Region	May 20 - May 31 (2014)	June-Aug 2014	Sept-Nov 2014	Dec (2014) - Feb (2015)	March-May 2015	June-Aug 2015	Sept-Nov 2015	Dec (2015) - Feb (2016)	March-May 2016
Kailahun	53.47%	41.33%	1.91%	0.13%	0.00%	0.00%	0.00%	0.00%	0.00%
Kenema	36.63%	31.77%	2.83%	0.38%	0.00%	0.00%	0.00%	0.00%	0.00%
Kono	0.00%	0.40%	1.72%	6.76%	0.37%	0.00%	0.00%	0.00%	0.00%
Kambia	0.00%	0.10%	1.54%	4.49%	19.93%	30.77%	83.33%	0.00%	0.00%
Koinadugu	0.00%	0.00%	1.72%	0.97%	0.37%	0.00%	0.00%	0.00%	0.00%
Bombali	0.99%	4.28%	16.10%	8.44%	5.17%	0.00%	16.67%	0.00%	0.00%
Tonkolili	0.00%	1.59%	7.32%	3.40%	0.37%	2.56%	0.00%	100.00%	0.00%
Port Loko	2.97%	6.57%	16.82%	22.00%	21.40%	35.90%	0.00%	0.00%	0.00%
Pujehun	0.00%	0.70%	0.49%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Bo	2.97%	4.68%	4.29%	2.31%	0.00%	0.00%	0.00%	0.00%	0.00%
Moyamba	0.99%	0.80%	3.10%	1.97%	0.74%	0.00%	0.00%	0.00%	0.00%
Bonthe	0.00%	0.10%	0.04%	0.08%	0.00%	0.00%	0.00%	0.00%	0.00%
Western Area Urban	1.98%	4.88%	25.51%	35.98%	42.44%	30.77%	0.00%	0.00%	0.00%
Western Area Rural	0.00%	2.79%	16.61%	13.10%	9.23%	0.00%	0.00%	0.00%	0.00%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	0.00%

Table 3. Percentage of confirmed cases in each district within Sierra Leone during each quarter. Quarters are independent from one another.