The Impact of Anthropogenic Change on the Transmission of Malaria in sub-Saharan Africa

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Introduction

Malaria is the most prevalent mosquito-transmitted disease in the world. The human race has had to contend with this ancient infirmity since we first began roaming the plains of Africa over 100,000 years ago. Since then, malaria has killed approximately 27 billion people (Fort et al., 2004, p. 131). Even today, malaria's potency remains very persistent. Each year between 300 to 500 million people will become infected, and 1 to 2 million of those people will die (Meade & Earickson, 2005, p. 77). And nearly 90% of those deaths are young children and pregnant women in the developing countries of sub-Saharan Africa (Johnston et al., 2002, p. 222). The morbidity and mortality rates remain high in sub-Saharan Africa despite the fact that malaria is both treatable and preventable. At the heart of this ongoing public health crisis are human activities that continually reshape the natural environment in such a way that it increases the geographic distribution and transmission rates of disease. The purpose of this paper is to examine some of the different anthropogenic activities that are responsible for the spatial distribution of malaria throughout sub-Saharan Africa.

Malaria, the Disease

Malaria is a serious and often fatal infectious disease. However, the disease is not contagious, and cannot be transmitted from person to person like the flu. People can only contract the disease when they are bitten by a female *Anopheles* mosquito which has been infected with a protozoan parasite, specifically *Plasmodium falciparum*, *Plasmodium vivax*, *Plasmodium malariae*, and *Plasmodium ovale* (Service, 2008, p. 36).

Depending on which species of the *Plasmodium* parasite a person has been infected with will determine the level of severity of the symptoms. The most virulent form of malaria, which is caused by *Plasmodium falciparum*, if left untreated, can cause anemia, jaundice, kidney failure, seizures, coma, and death. In fact, *P. falciparum* kills up to 40% of its victims (Humphreys, 2001, p. 9).

Malarial morbidity and mortality rates vary from region to region in sub-Saharan Africa. There are a variety of transmission mechanisms, some of which fall under either environmental or anthropogenic classifications. These determinants can be substantially different between communities, towns, cities, and countries. So, no single factor can be identified as the primary cause of malaria (Fosu & Mwabu, 2007, p. 13).

Normal Determining Factors

Mosquitoes and their vector-borne diseases are found throughout the world, except in areas that are permanently frozen over. Approximately 75% of all mosquito species reside in the world's tropical and subtropical regions (Reiter, 2001, p. 142). The survival of mosquitoes and their diseases are strongly influenced by environmental factors. Specific climatic conditions such as air temperature and precipitation help set the geographic limits for malaria transmittance (Reiter, 2001, p. 149).

Air temperature is a very important environmental factor that influences malaria transmission. *Anopheles* mosquitoes need air temperatures to be between 25°C and 27°C for optimum breeding, feeding, and cellular metabolism. Likewise, warm air temperatures are also crucial for the development of the *Plasmodium* parasite. In this case temperatures need to be between 20°C and 30°C (Service, 2008, p. 37).

The intensity in which malaria is transmitted often hinges the minimum and maximum temperature ranges in which the vector and parasite reside. However, mosquitoes are quite resilient. They use highly adaptive survival strategies to protect themselves against extreme temperature fluctuations. In the Sudan where air temperatures often exceed 55°C, *Anopheles* *gambiae* will often hide in thatched roofs during the heat of the day, and then emerge after dusk to feed. Likewise, in the cooler highlands of Kenya where temperatures drop below 18°C, *A. gambiae* will often seek refuse indoors where air temperatures can be 5°C warmer (Reiter, 2001, p. 142,152).

Anopheles mosquitoes, like all mosquitoes, require water habitats in which to breed. Therefore, the right amount of precipitation is required in order for the mosquito to complete its life-cycle. Too much, or too little rainfall can adversely impact mosquito populations. For the most part, rainfall rates need to be between 50mm and 80mm each month for the creation of adequately-sized pools of standing water (Kovats et al., 2001, p. 1066).

Not only the amount and intensity of precipitation affects malaria transmission, but so to does the time of the year. When periods of heavy rains follow a prolonged drought, there is the potential for a malaria epidemic. For example, in 1996 Zimbabwe experienced its first rainy season following a 5 year drought. By the end of the seven month rainy season 828 people died, and over 300,000 people contracted malaria. Conversely, during the same drought-ridden seven month period the year prior, only 130 people died, and just over 100,000 people became infected (Aron & Patz, 2001, p. 358). The primary cause for the jump in cases of malaria was the increase in rainfall. However, heavy rainfall is not always beneficial to mosquito and malaria production. Sometimes heavy rains can reduce mosquito populations by washing away developing eggs and larvae, thus reducing the potential for a malaria outbreak.

The transmission and distribution of malaria has always had close ties to the environment. However, human activities are altering the environment in ways that contribute to the emergence of mosquito-borne diseases. These anthropogenic factors often outpace the normal spatial distribution of such diseases when compared to normal environmental factors.

Anthropogenic Determinants

Infectious diseases, like malaria, can emerge as a result of natural or unnatural changes to the environment. Beyond the normal environmental determinants, anthropogenic determinants can influence the distribution of the disease by directly modifying the behavior and geographical distribution of the *Anopheles* mosquitoes (Aron & Patz, 2001, p. 353-354). Over the past two centuries anthropogenic factors such as deforestation, agriculture, irrigation, population increase, migration, and war have all influenced the spatial distribution pattern of malaria throughout sub-Saharan Africa (Fort et al., 2004, p. 138-140).

Deforestation

Deforestation has become a common anthropogenic activity around the world, and across the sub-African continent. Most deforestation in sub-Saharan Africa has been fueled by a rising demand for forest services such as food, wood, mineral exploration, and paper products. Over the last two decades, it has destroyed nearly 10% of the sub-Saharan tropical rain forests. The amount of destruction inflicted on tropical rain forests since 1990 equals roughly 8 million hectares, or 20 million acres (Kneeland & Ball, 2007, p. viii, 5). The sub-Saharan countries with the highest rates of deforestation include: Democratic Republic of Congo, Nigeria, Zambia, and the Sudan; most of these countries also have high transmission rates of malaria (Kneeland & Ball, 2007, p. 109-110).

The process of clearing forests eliminates most if not all native flora and fauna. The eradication of both plant and animal species can have a profound impact on the survivability of malaria. For instance, deforestation can eliminate species which naturally prey on mosquitoes. There are many species of tropical bats and birds which can feed on thousands of mosquitoes each day (Tuttle, 2006, p. 1). The removal of these natural mosquito predators can increase the likelihood of future outbreaks.

Deforestation can also impact public health systems by destroying medicinal plants and trees which can be cultivated to produce life-saving medicines. For example, Quinine, considered by many in the public health field as the most successful antimalarial drug, was derived from the bark of the Cinchona tree (Rocco, 2003, p. 281). What's more, throughout rural and forested communities many people still rely on medicine men as their primary means of health care. These traditional healers use the pharmaceutical properties of medicinal plants and tress found exclusively in tropical rain forests to treat many different aliments (Willcox et al., 2004, p. 4).

Deforestation also has an enormous impact on local ecosystems. It alters microclimates by reducing shade, altering rainfall patterns, augmenting air movement, and changing humidity levels. It also increases surface water availability through the loss of topsoil and vegetation root systems that absorb rain water (Cartledge, 1994, p. 135-136). Some *Anopheles* mosquitoes prefer to breed in shaded pools of water, which can reduce their breeding habitats, thus affecting their population numbers. Conversely, some environmental and climatic changes due to deforestation can increase the survival rate of other *Anopheles* species, resulting in prolonged seasonal malaria transmission rates (Service, 2008, p. 37-38). Even though some *Anopheles* species will be directly impacted by deforestation, most will adapt to the new environmental conditions. As a result, malaria rates will remain high and any human populations that move in and attempt to cultivate the newly cleared patches of forest will increase their chances for contracting malaria (Cartledge, 1994, p. 142).

Agriculture and Irrigation

The rise in agriculture practices in sub-Saharan Africa has been the result of favorable geography as well as public policies that encourage agricultural development. The spatial distribution of malaria has long been linked to agricultural development. The clearing of forests for crop production, and the tilling of moist soil often exposes small pools of standing water, which allows mosquitoes to breed. In addition to agricultural practices, the availability of livestock is another key factor for the transmission of malaria. Livestock attract mosquitoes. So when the opportunity arises, the mosquitoes will then feed on the nearby human populations (Mayer & Pizer, 2008, p.389).

The population explosion in the sub-Saharan African countries has led to an increased demand for food that is far exceeding normal agricultural production. In order to meet this need, many governments have instituted large-scale irrigation projects. Although crop irrigation provides a solution to alleviating the demand for much needed food resources, it also can introduce malaria in local communities at much higher rates.

The negative health impacts associated with irrigation development in hot tropical climates is well known. The influence of African irrigation schemes has provided more favorable environments for malaria vectors. The building of small dams and irrigation canals create prime breeding grounds for mosquitoes (Packard, 2007, p. 12-13). In fact, in the Republic of Burundi, malaria transmission rates are 70% higher near irrigated rice fields. Likewise, in the highlands of Kenya, irrigated cotton and vegetable farms experience nearly 55% higher incidents of malaria when compared to non-irrigated farms (Mutero et al., 2006, p. 1). What's more, in the Sudan during the 1970s, the Gezira water irrigation program which was designed to transform large tracts of arid landscape into prime farm land ended up creating a malaria epidemic in an area where the disease was once under control. Even today, over 100,000 malaria cases are still reported annually at Gezira (Fort et al., 2004, p. 138).

For the most part, the linkage between malaria and irrigation only exists in regions where malaria is not currently endemic, or where people have little or no immunity to the disease. In regions where malaria currently exists, the introduction of crops and irrigation has little impact on malaria transmission rates (Packard, 2007, p. 269). However, these natural balances can all be thrown asunder by massive population movements.

Population and Migration

Massive population movements have been a normal feature of sub-Saharan Africa since the dawn of man. There is no phase of malaria which can be understood without the migratory movements of people. What's more, there are few contemporary problems in the fields of public health, politics, and socioeconomic development in Africa which are not influenced by migration and malaria.

The relationship between malaria and large-scale population movements can be quite complex. For instance, there is a positive correlation between the number of people and *Anopheles* mosquitoes living in a particular region, and the intensity in which the disease can be transmitted. When both population densities are high, there is a greater likelihood malaria will be transmitted. When both population densities are low, the transmission of malaria will be less intense (Packard, 2007, p. 24-25). The complexity is compounded even further when environmental and ecological determining factors are taken into account. Nevertheless, as human populations migrate, so to do the mosquitoes that can carry the malaria parasite.

Migrations and forced-migrations are often the result of strong push and pull factors. Migrations can begin because war, famine, drought, or natural hazards. Or they can be voluntary in nature, such as the search for better seasonal employment opportunities on distant agricultural lands. Prothero (1965), a malaria consultant to the World Health Organization, agrees and states that “some agricultural communities in Africa are cultivated of distances of up to ten miles from permanent settlements” (p. 35). For example, each year thousands of Kenyan tea plantation workers will migrate many miles from their urban residences to rural agriculture lands in search of seasonal employment. As a result, there are often increased incidences of malaria along the migration routes (Bloland & Williams, 2003, p. 8-11).

For the longest time malaria was considered to be a rural disease. The only time urban populations came in contact with the disease was either during large-scale migrations traversing through agrestic regions, or individuals traveling in and out of highly malarious areas for business or pleasure. But those days have past; today, more and more sub-Saharan Africans live in booming urban centers. As a result, malaria has begun moving into highly urban developments.

Urbanization

Although Africa has been described as the least urbanized continent, it still has the highest rates of urban development anywhere in the world. The rapid advancement of urbanization in sub-Saharan Africa has been quite staggering. Consider the fact that in 1960 there were no cities south of the Sahara desert with populations over 1 million. Today, there are now forty. By the year 2025 it is estimated that approximately 800 million people will be living in sub-Saharan African cities; and those totals are expected to triple by 2050 (Donnelly et al., 2005, p. 1-2).

It is generally believed that the rates of malaria decrease as urbanization increases. It’s true that good urban development practices can be responsible for the decreasing malaria transmission by reducing human-mosquito contact, but bad urban development practices can have the opposite effect. For instance, substandard housing and poor designed sanitation and drainage systems can often attract higher densities of mosquitoes. Reiter (2001), medical entomologist for the World Health Organization, writes “in rapidly expanding urban areas, extensive water storage and inadequate water disposal can lead to disastrously high mosquito populations” (p. 150). These high mosquito populations living in close proximity to millions of people create ideal conditions for malaria epidemics. What’s more, there is recent scientific evidence showing that many species of the *Anopheles* mosquitoes have begun adapting to urban man-made aquatic ecosystems. In new urban developments in Ghana and Kenya, *A. gambiae* has shown its preference to breed in household water-filled receptacles and drainage systems, rather than nearby natural ecosystems (Robert et al., 2003, p. 172).

War and Civil Strife

Just as urbanization and migration has influenced the transmission of malaria, so too has war and social unrest. Virtually every geographic region on the African continent has been affected by war and civil strife. Conflicts have been caused by many factors including: cultural, economic, political, and social issues. How and why each conflict began is different, however, what each conflict has in common is that they often promote the transmission of malaria. According to Packard (2007), “the global resurgence of malaria since the late 1960s has been driven by political upheavals, warfare, and the massive displacement of human populations” (p. 193). Wars and social unrest further exacerbate the transmission of malaria by collapsing public health infrastructures, public works facilities, destroying countless homes, and displacing large numbers of people (Reiter, 2001. p. 150).

Numerous sub-Saharan African countries have experienced devastating crises as the result of war and malaria. For example, during the civil war of the 1990s in the Democratic Republic of Congo, approximately 2.5 million people died alone from infectious diseases such as malaria (Forte et al., 2004, p. 140). In addition, malaria was one of the leading causes of death in the Rwandan refugee camps in Zaire, as well as Ethiopian refugees in eastern Sudan during the mid-to-late 1990s (Boland & Williams, 2003, p. 11-13).

In addition to the human costs, war and civil unrest can also change the natural environment in ways that make malaria development much more conducive. McCoy (1944), of the Office of the U.S. Surgeon General, explains, “Wartime activities can change the malaria picture by clearing jungle undergrowth for base areas…shell holes, bomb craters and road ruts also create new breeding places” (p. 538). Of course most of these anthropogenic changes to the environment will gradually disappear as the conflict dissipates. However, the damage is already done. The disturbed environmental conditions will continue to favor the future transmission of infectious diseases such as malaria.

Conclusion

In closing, malaria today is on the decline in many parts of the world, however, one of its last and most formidable geographic strongholds remains sub-Saharan Africa. The future impact of malaria on the emerging sub-Saharan African urban populations will be based primarily on the extent of anthropogenic activities. As stated before, temperature and precipitation are the main natural limiting factors that affect the normal spatial distribution of mosquitoes that transmit malaria. However, in areas where humans impact the natural environment with agriculture, deforestation, migration, urbanization, and war can also significantly influence malaria epidemics. Therefore, in order to decrease the extent to which humans influence the spread of mosquito-borne diseases such as malaria, there needs to be better public health awareness, as well as a stronger political will from African governments to help reduce the amount and intensity to which future anthropogenic activities will occur.

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