Aedes aegypti and Dengue in the Philippines: Centering History and Critiquing Ecological and Public Health Approaches to Mosquito-borne Disease in the Greater Asian Pacific

Maria R. Pettis  
*Pomona College*

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Aedes aegypti and Dengue in the Philippines: Centering History and Critiquing Ecological and Public Health Approaches to Mosquito-borne Disease in the Greater Asian Pacific

Maria Pettis

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Readers:
Wallace (Marty) Meyer
Francisco Dóñez
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Abstract

The global incidence of dengue has increased 30-fold over the past 50 years in the western or Asian Pacific, this region is also a contemporary epicenter for resource extraction and ecological destabilization. Dengue is addition to yellow fever, chikungunya and most recently zika virus, are transmitted by the mosquito vector Aedes aegypti - a domesticated mosquito adept at breeding in artificial household containers and within homes. The history of the domestication and global distribution of Aedes aegypti is intrinsically linked to European expansion into and among tropical worlds. Contemporary population genetics research suggest the westward expansion of the mosquito vector beginning with trans-Atlantic Slave Trade moving to the Americas and then making a jump across the Pacific, which I argue occurred first within the Philippines and then spread eastward through the greater Indian Ocean. I argue that Spanish and American colonization facilitated the biological invasion of Ae. aegypti and dengue in the Philippines and created the conditions for contemporary epidemics. The discourse within the dominant voices of public health, CDC and WHO, omit this history as well as down play the significance of land use and deforestation while focusing predominantly upon dengue’s prevention and control. This omission is an act of erasure and a means of furthering western imperialism through paternalistic interventions. Mosquito-borne disease epidemics are unintended consequences of past human action and if public health discourse continues to frame epidemics as random and unfortunate events, we risk missing key patterns and continuing to perpetuate the circumstances of disease and adaptation.
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Argument

The contemporary global distribution of the mosquito vector *Aedes aegypti* as well as epidemics of mosquito-borne disease are a legacy of colonialism and are intrinsically linked to environmental history and to European expansion into and among tropical worlds. Contemporary population genetics research suggests the westward expansion of *Aedes aegypti*, the domesticated mosquito vector and transmitter of not only dengue but also yellow fever, chikungunya and recently, the zika virus (Powell et al 2016). Contemporary public health literature and discourse from the Centers of Disease Control (CDC) and World Health Organization (WHO) frame *Aedes aegypti* and the pathogens it transmits, particularly dengue, as endemic or naturally occurring throughout global tropical and subtropical regions. However, this is a misrepresentation that lacks historical grounding. These organizations are dominant voices in public health and tropical medicine and the absence of origin or connection to colonial or environmental history in their discourse allows them to frame and perpetuate a narrative that the distribution of epidemics of mosquito-borne disease are inevitable, random, and unfortunate events as opposed to unintended consequences of human action set forth by imperial activity. To be clear, with regards to *Aedes aegypti* and dengue, human agency is key in the discourse of public health, but it is targeted and intentionally focused on correcting the ‘behavior’ of individuals in tropical worlds rather than addressing the implications of land use or globalization.

In the case of the Philippines and greater Indian Ocean, contemporary mosquito-borne epidemics, particularly those transmitted by *Aedes aegypti*, and their distributions are anthropogenic or human-caused consequences, intrinsically linked to Spanish and American colonial legacies and environmental history. The Philippines is a key location to study mosquito borne-disease, particularly dengue, as it historically has been a corridor between two worlds, on
the periphery of ancient Indian Ocean trade routes and the destination of cyclic annual Spanish Manila Galleons — voyages which traversed the Pacific between Acapulco, Mexico, and Manila (Figure 1). In addition to surviving more than 300 years of exploitation under Spanish colonial rule, the Philippines was further buffeted by revolution and war in the late 19th and well into the 20th the century. As the United States took control, Filipinos revolted and the country was occupied by Japan during World War II.

Contextualizing and historically situating Aedes aegypti and dengue in the Asia Pacific is necessary and essential to understanding large-scale spatial and temporal patterns and the conditions that create or facilitate mosquito-borne epidemics. Mosquito-borne epidemics, defined as widespread occurrences of disease within a population at a given time, have four basic requirements: 1) a densely populated non-immune human population, 2) susceptible environments that contain numerous shallow sunlit pools of water, 3) ample populations of the mosquito vector, in our case Ae. aegypti, 4) And the pathogen, in this instance dengue, to be passed between human and mosquito (Figure 2). This work details how each of these four
conditions was created in the Philippines around the turn of the century, followed by cyclic epidemics of dengue starting in Manila in 1906 that have continued into the present.

In short, I attempt to examine how the Spanish and American occupations of the Philippines altered landscapes via the growth in sugar production and urbanization, making the Philippines more hospitable to the biological invasion and colonization of new mosquitoes. I argue that not only land but also urban centers were made hospitable and vulnerable to mosquitoes. Spanish imperialists and Catholic friars created the foundations of large-scale sugar plantations called haciendas in addition to importing architecture and constructed buildings that facilitated the growth of mosquito populations, *Ae. aegypti*, a mosquito specialized to breed in artificial man-made containers (Schultz, 1985; Gibbons et al. 2012). Further, Spanish trading ships — the Manila Galleons — were likely the first means for the passive transportation of *Ae. aegypti* from the New World. The 250-plus galleons transported goods from Manila and Acapulco and likely returned to Manila with mosquitoes breeding aboard in open water cisterns.
In the 18th and 19th centuries, the creation of a plantation-based economy altered not only natural resource cycles, likely increasing the abundance of shallow pools of water and elevating ground temperatures, but also caused a shift in the geography of Filipinos, creating large, dense human populations — ripe conditions for mosquito-borne epidemics. Large, concentrated labor forces were needed not only on sugar and more recently rubber and palm oil plantations for production and processing, but also in port cities, in particular the capital Manila (Larkin, 1993).

The end of the Spanish Manila Galleons, the growth of trans-Pacific commerce and the development of steamships pre-1898, decreased the time it took to travel between the Americas and the Asia Pacific. Whereas the Manila Galleons’ five-month voyages likely served as a barrier for the active transmission of disease, the transition to the use of steamships in the mid-19th century cut travel time to a few weeks. The onset of rapid transport, a factor in globalization, likely increased the transmission of disease and the trans-Pacific spread of dengue. I argue that dengue was likely first introduced into the Philippines among the bodies of Western merchants and/or soldiers around the time of the Spanish-American and Philippine-American wars. Official reports note the disease circulating among American soldiers as early as 1902 (Siler, 1926). Pathogens hitched a ride among people and the infected mosquitoes, forming the basis of cyclical disease dynamics with dengue jumping from mosquito to person and back again in late 19th and early 20th century Manila. In addition to steam and rapid transport. The wars transported large numbers of military personnel via ship from San Francisco to Hawaii and from the Nicaragua Canal to Manila, regions with pre-existent incidences of dengue (Russell, 1899; Nicaragua Canal Commission, 1899).

The urbanization of Manila and other port cities was driven by the need for cheap labor to maintain the mass import and export of goods. It was also an American military tactic to quell
indigenous resistance under the Reconcentration Act of 1903, following the Philippine-American War. There have since been cyclic patterns of epidemics throughout the 20th century in port cities and urban centers throughout the Asia Pacific: Hawaii in 1903; the Philippines in 1906; and India, Malaysia and Thailand in the 1910s (Winchester and Kapan, 2013; Siler, 1926; Smith, 1956). There are four known serotypes of dengue DEN-1-4, each of which confer lifelong immunity to survivors yet the more serotypes an individual is infected with, the more likely they are to develop dengue hemorrhagic fever, the most deadly variety. Dengue hemorrhagic fever emerged around the same time in both the Philippines and Thailand and coincides with World War II. The pathogen then spread around the Asia Pacific and is now found in global tropical and subtropical regions along with Ae. aegypti populations (Mackenzie et al 2004).

While John McNiell’s Mosquito Empires: War in the Greater Caribbean details the trans-Atlantic movement of mosquitoes and pathogens, discourse on the subject lacks a unifying text or premise for the further westward jump into the Asia Pacific. This contribution attempts to nuance this gap in history. I suggest the need for regional expansion of McNiell’s research, emphasizing his promising historical-geographical approach within the case study of the Philippines in an attempt to tease-out the present circumstances of Aedes aegypti and dengue in the Asia Pacific.

Ecological research published in the past five years concerning the population genetics of Aedes aegypti has helped to dispel the notion of endemicity. This is significant. If we fail to see large-scale trends and patterns we risk perpetuating the conditions that allow the pathogen to prevail. The emergence of drug- and insecticide-resistant mosquitoes and pathogens suggest an alarming trend of adaptation to conventional control measures (Marcobe et al 2012; Brathwaite Dick et al 2012). This research provides a social-historical context and environmental history lacking in
studies of both dengue and *Aedes aegypti* in the Philippines and greater Asia Pacific. While a new dengue vaccine has been introduced into the Philippines as of the spring of 2016, it is only 50 percent effective. The region is now also witnessing the rise of a new pathogen circulating among people and *Aedes aegypti* mosquitoes, the zika virus. Further, increased deforestation efforts pose an imminent threat to public health. This thesis stresses a proactive versus re-active public health approach to mosquito borne-disease.

Current public health literature from the WHO and CDC, including dengue fact sheets, reference sources and guidelines on prevention and control, lack depth and clarity about the regional origins of mosquitoes (CDC Dengue Factsheet; WHO Dengue Guidelines 2009; WHO Dengue Global Strategy 2012-2020). The language conveys a sense of general endemicity of both mosquitoes and pathogens. Their silence on the history and regional origins of vectors and pathogens is a failure to contextualize and extrapolate the spread of the disease vis-a-vis the abuse of power by imperial regimes, while narrowly focusing on problems with hygiene.

To reiterate, in the context of public health and the amelioration of mosquito-borne disease, human agency is key. Dominant public health and tropical medicine discourse works on two levels: it detracts from history and the activity and lasting influence of colonial regimes by focusing solely on contemporary prevention and control. It frames mosquito-borne epidemics as an issue of hygiene, lack of urban planning and development and portrays those affected as unhygienic, uneducated and under-resourced victims. The language implies that victims of dengue are in need of solutions that require paternalistic guidance and oversight of national and international public health organizations. Present in the discourse are undertones of ineptitude among affected peoples in tropical and urban centers. The CDC and WHO wield influence over
discourse and public/global health policy and investment — another imperialistic imposition of authority and influence by the United States and Europe.

Some Key and Overarching Questions I attempt to address:

- How and why did *Aedes aegypti* invade and colonize the Philippines?
- Why did dengue then invade and colonize the bodies of mosquitoes and people in the Philippines, reaching the current state of endemic and epidemic proportions?
- What are the circumstances that spurred the introduction of *Aedes aegypti* and dengue into the Philippines?
- How and why were human populations and landscapes made to be susceptible to the colonization of *Aedes aegypti*?
- Why do mosquito-borne epidemics continue?
- What are the circumstances surrounding the emergence and increase of drug and insecticide resistant cases in the Philippines and more broadly the Asia Pacific?

**Section 1: Science and the Philippines**

**1.1 Literature Review/ Scientific Background**

Mosquito-borne disease is a significant and contemporary public health issue. WHO estimates that 50 to 100 million infections of dengue occur annually in more than 100 countries — a 30-fold increase within the past 50 years. Epidemics on the increase also include the zika virus and drug-resistant malaria. Insecticide-resistant *Ae. aegypti* and *Anopheles* mosquitoes are also becoming prolific (Jones et al. 2008; Sehgal R. 2010; Marcobe et al 2012; van der Ploeg et al. 2011). Dengue is spread primarily by the domesticated mosquito vector *Aedes aegypti*, which is also responsible for transmitting yellow fever, chikungunya and more recently zika fever.
Malaria, another key mosquito-borne disease is caused by plasmodia spread by multiple species of Anopheles mosquitoes; 3.2 billion people — almost half of the world’s population — were at risk for it in 2015. In 2014, 154 million people were at risk for malaria in the Asian Pacific region alone.

According to the CDC and the WHO, mosquito-borne diseases occur mostly in tropical and subtropical regions, primarily impacting populations in South America and Asia or the Western Pacific. Dengue is characterized by symptoms including, high fever, chills, rash or red spots, and muscle and joint pain. In severe cases, such as dengue hemorrhagic fever, there is serious bleeding and shock, which can be life threatening. Nausea, vomiting and loss of appetite are common (CDC, 2016). Dengue, in particular, is described as a “disease of poverty” that mostly affects “tropical urban centers with mass unplanned urbanization,” whereas malaria is described as a disease afflicting poor people in “rural regions without access to adequate healthcare” (WHO Malaria, 2016). Global strategy for dengue prevention and control 2012–2020; CDC-Malaria FAQs; Mulligan et al 2015). There is no accompanying reference to or indication of the origins or historical-geographic spread of mosquito vectors or pathogens into these regions. This absence in major public health information centers seems to imply that these diseases are endemic i.e., having constant or usual presence in these regions.

Zoonotic diseases, those spread between animals and people, are complex and are influenced by a combination of variables. There is consensus in recent ecological literature that human-caused land-use change, primarily deforestation and agricultural land conversion, are among the most important drivers affecting the populations of mosquito vectors and the pathogens they carry (Walsh et al. 1993; Guerra et al. 2006; Yasouka and Levins 2007; Jones et al. 2008; Olson et al. 2010; Forance et al. 2016). The connection of mosquito-borne disease to land use change and
Deforestation is largely absent in publications and online sources from the CDC and WHO 2016. The tropical and subtropical regions in the Americas and the Asian Pacific are centers of growing mosquito-borne epidemics and drug and insecticide resistance. These regions are also host to rising rates of landscape transformation, including deforestation and agricultural land conversion from palm oil, rubber and sugar plantations (Saatchi et al. 2011; al. 2010; Reboredo, F. 2013; St. Laurent et al. 2016). The linkages of disease to multiple factors is echoed by Sehgal’s 2010 study of avian zoonotic diseases, which connects the increase in avian malaria to climate change, invasive species, urbanization and, most significantly, deforestation that drives habitat loss and the condensation of migrating avian populations. In addition to deforestation, mosquito domestication and adaptation to human-caused changes are key drivers for the proliferation of vectors of dengue which are responsible for multiple arboviruses. These arboviruses or a group of viruses transmitted by arthropods, (mosquitoes) that transmit dengue, zika, yellow fever and chikungunya from Ae. aegypti and malaria from Anopheles mosquitos. Reports from the CDC indicate that Ae. aegypti is domesticated, that is closely associated with human dwellings and exhibits a prefer to breed in artificial containers like tires, pots and plastic bowls. Researchers like Sehgal 2010, Jones et al. 2008 and others have found that Ae. Aegypti is resilient and very difficult to eradicate. The species is said to be constantly adapting to new and changing environments. It’s the first to bounce back after natural disasters or insecticidal spraying. The WHO is aware of a growing problem of drug and insecticide resistance as stated in its 2012 report, Global Plan for Insecticide Resistance and Management: “Resistance is known to affect all major malaria vector species and all four recommended classes of insecticides. Since 2010, a total of 60 countries have reported resistance to at least one class of insecticide, with a total of 49 of those countries reporting resistance to two or more classes.”
While the Americas and Asian Pacific together contain 73 percent of the world’s tropical forest cover, the Asian Pacific alone bears 75 percent of global dengue incidence (Saatchi et al. 2011; WHO: Dengue Guideline, 2008). The rate of tropical deforestation in the Philippines averaged 47,000 ha of forests per year from 1990-2010, while the rate of annual tropical forest conversion in the leading palm oil exporting countries totaled 270,000 ha (UN FAO, 2016). In recent ecology literature, numerous authors support the claim that human-caused land use change, mainly deforestation, has important implications for mosquito vectors and zoonotic disease. However, there is no clear consensus on the universal effect of land-use changes when comparing different regions. Yasouka and Levins 2007 in a cross-regional and multiple species analysis found that mosquito populations react differently to development, e.g. deforestation and agricultural land conversion, and that these reactions are species specific. Guerra et al. 2006 cites South America’s slash-and-burn techniques as a cause for increasing local malaria rates and argues that deforestation contributes to larger mosquito populations in the South American Amazon and in Central Africa, but lower mosquito populations in Southeast Asia. Guerra’s assertion contradicts recent findings from Force et al. 2016, which suggests that deforestation is actually linked to higher incidence of Plasmodium knowlesi, a malaria plasmodium widely associated with forest dwelling mosquitoes and old world monkeys. However, the linkages depend on scale and distance of analysis. Previous research in S.E. Asia has procured variable results about linkages of malaria to deforestation on a regional scale. But Force et al. 2016 found that on a smaller, sub-district scale there is a positive association between higher forest loss and malaria in villages located within 2 kilometers of forest loss. Olson et al. 2010 concurs with findings from Guerra et al. 2006 on deforestation and malaria in Brazil, which found that a decrease in forests of just 4.8 percent was connected to a 48 percent increase in surrounding
malaria incidence in the Brazilian Amazon. Other studies conducted in Sub-Saharan Africa, the Amazon, and Northwest Thailand, like Taber and Smithwick 2015, Vittor et al. 2006 and 2009, and Weterings et al. 2014, investigate the importance of protected areas and buffer zones for natural mosquito larvae predation. They found that not only does deforestation increase certain mosquito populations but it also increases their activity and biting rates. The literature reviewed here connects specific actions like slash and burn, logging and buffer zones to the prevalence of mosquitoes and their behavior, yet these actions and connections are missing in major public health discourse such as WHO’s 2012-2020 publication: Dengue Global Strategy Prevention and Control.

The CDC and WHO make generalizing claims such as epidemics occur in tropical regions with ‘poverty and unplanned urbanization,’ and either downplay or omit the dynamic ecological findings with causal implications such as slash and burn, Guerra et al. 2006, or deforestation and higher malaria incidence in Indonesia, Force et al. 2016. This is true in the case of the WHO publication: Eliminating Malaria: Progress Toward Subnational Elimination in the Philippines. The paper mentions an instance of slash and burn once and makes no mention of deforestation or forest loss, but provides ample references to cases of malaria contracted by individuals living near forests or on forest fringes. Aside from blaming “poverty and unplanned urbanization,” WHO and CDC fact sheets ignore the question of cause for the current state of epidemics and concentration of poverty in urban centers. There is no attempt to explain why or how unplanned urbanization occurred. These organizations focus on mitigation and prevention efforts rather than on the historical conditions that create or foster epidemics. They largely ignore the crucial importance of forests, emphasized by studies published within the past five years, and the significance of intact ecosystems and buffer zones in regards to naturally controlling mosquito
populations (WHO: “Dengue, Guidelines for Diagnosis, Treatment, Prevention and Control,” 2009). The lack of analysis for cause is also evident in the CDC’s description of “dengue hemorrhagic fever as first identified in 1950s Philippines and Thailand and being prolific in Latin America and Asian Pacific today,” where again I find no causal attributes reported.

Further, studies like Karayan et al. 2008 that investigate the emergence of drug resistant malaria plasmodium in Indonesia, point to both treatment failure and migration as creating susceptible populations. While treatment failure and over-use of organochlorine insecticides like DDT in agriculture are common causes of drug resistance according to WHO, references to actions like human migration or land conversion are often glossed over in its publications, like the 2011 position statement on “The use of DDT in malaria vector control,” that highlights the need for an understanding of local ecology and community engagement, and cites “treatment failure” but provides no further analysis. While drug-resistant malaria is an issue of increasing importance to both WHO and the CDC, it is an issue also without clear origins.

Although the Indian and Pacific Ocean worlds bear the brunt of contemporary dengue incidences, mosquito-borne disease and mosquito vectors have a unique and complicated history of global expansion. The ancestral predecessors of *Aedes aegypti* are native to continental Africa, and this species is thought to have evolved and domesticated during the period of the Trans-Atlantic slave trade in the New World. It was reintroduced in port cities in West Africa. Dengue was first recognized in the New World and Caribbean. Both mosquito and pathogen are today found in the majority of the tropical and subtropical regions of the world. JR. McNeill in his 2010 book, “Mosquito Empires: War in the Greater Caribbean 1620-1914”, traces the complicated history of both *Aedes aegypti* and its transmission of yellow fever from its ancestral forms in Africa to the Americas. McNeill also provides a comprehensive examination of how
mosquitoes capitalized on ecological destabilization following the production of sugar, which spurred deforestation and land conversion, making land hospitable and vulnerable to mosquito colonization. The plantations contributed to soil erosion and loss of forest cover, especially on islands, setting off a chain of events often leading to the creation of marsh-like conditions on coasts where mosquito populations then exploded. These increases were typically followed by subsequent epidemics of yellow fever. McNeill details how the import of both African slaves and Europeans brought consistent introductions and reintroductions of new pathogens, i.e., yellow fever and malaria, to new non-immune indigenous human populations. While McNeill provides a context for the trans-Atlantic expansion and domestication of *Aedes aegypti* and virulent evolution of dengue, the scope of this thesis provides context for the further westward trans-Pacific expansion of this domesticated vector and pathogen from the New World into the Pacific and Indian Ocean by way of the Philippines.

Contemporary population genetic research affirms the idea of global westward *Ae. aegypti* expansion, Powell et al. (2013), cite evidence of genetic similarities of New World mosquito populations and those in Thailand and New Zealand, furthering the idea that populations of *Ae. aegypti* were established by New World populations moving across the Pacific Ocean (Figure 3). Further new ecological and entomological research suggest that the domesticated vector *Aedes aegypti* as it exists in the Americas and Asian Pacific today, differs from the largely forest-dwelling species in Africa where not otherwise reintroduced by trade ships in African ports (Powell et al. 2013). Key portions of thesis are grounded in contemporary genetic research, and it is here that biological research is used to help uncover, nuance, and piece together subtle and ignored historical events of dramatic and lasting impact.
There seems to be a consensus in the literature that *Aedes aegypti* was introduced into the Philippines around the end of the 19th century and was followed by the introduction and spread of dengue (Powell et al. 2013). However, there is little social or historical context for the introduction of the mosquito vector and the dengue pathogen in the Philippines and greater Asian Pacific.

Understanding contemporary zoonotic epidemics as a consequence of circumstance set forth by colonization and the slave trade helps to frame mosquito-borne epidemics as a part of a larger process of change and migration rather than a random unfortunate phenomena. However, no such approach or set of texts serves as a converging or unifying voice for the origin and introduction of pathogens in the Philippines or greater Indian and Pacific Ocean worlds. While some emerging discourse places American military intervention and WWII into the time frame of...
of the introduction of the emergence of the deadly dengue hemorrhagic fever and *Ae. aegypti* in the Philippines and Thailand, I propose that the mosquitos and dengue pathogen were introduced and became prolific in the context of larger and earlier events beginning under the Spanish colonial regime.

Public health and tropical medicine and hygiene sources such as a 1926 book by J.F. Siler and A.P. Hichens, “Dengue: Its History, Epidemiology, Mechanism of Transmission, Etiology, Clinical Manifestations, Immunity and Prevention,” makes reference to records of epidemics within American military soldiers in the Philippines occurring as early as 1902.

Contextualizing and historically situating *Aedes aegypti* and dengue in the Asian Pacific is necessary and essential to understanding large-scale spatial and temporal patterns and the conditions that create or facilitate these epidemics. This work attempts to assemble disparate historical documents and contemporary evolutionary/ecological research to pinpoint both a method and a time frame of the introduction of *Aedes aegypti* and the social and ecological context surrounding the emergence, spread and rise of epidemics of dengue and dengue hemorrhagic fever. What is not cited or mentioned in the conversation about the origins of *Aedes aegypti* is the extensive Spanish trade routes, design of ships, conversion of land for plantation spice production and interconnections within the already extensive travel and trade networks within the Indian Ocean (WHO Dengue, 2016; WPRO 2016). There are multiple parallels that can be drawn from the history of mosquitoes and disease in the New World that may have been replicated with the colonization of the Asian Pacific, beginning with the Spanish within Philippines. This work may help shed light on both contemporary epidemics and nuance the overlooked mechanism for past mosquito invasions in this region as well as provide a new view of the lasting social and ecological impacts of colonial regimes on the Indian Ocean.
These deficiencies highlight the need for a unified approach, which instead of presenting fragmented information, can speak to common trends and patterns of origin across different disciplines and modes of research. This approach has been seen in a few recent texts such as Brathwaite Dick et al. 2012, “History of Dengue in Americas,” which posits that dengue epidemics occur in 3 to 5 year cycles, and a pattern that would have likely been missed using different methods which tend to isolate individual case studies. Recent studies are dismantling the common notion that epidemics occur at random. Olson et al.’s 2010 study, for-instance, emphasized the idea that malaria epidemics have a lag time in the Amazon and tend to occur in areas where deforestation occurred 5 to 10 years before. They posit a frontier malaria theory and use a comprehensive approach tracking epidemics across time and space that allows the identification of patterns emerging over decades.

1.2: A Contemporary Case for the Philippines

The Philippines archipelago is the ideal case study to investigate the origins of Aedes aegypti, dengue and drug- and insecticide-resistant malaria in the Asian Pacific. Several studies have pointed to the periods around the Spanish-American War, Philippine-American War, and WWII as coinciding with mosquito introductions and epidemics and the emergence of dengue hemorrhagic fever (Powell et al 2013; Siler 1926; Smith 1956; Mackenzie 2004). Additionally, the Philippines is still experiencing thousands of cases of dengue and malaria each year (WPRO, 2016). Understanding the influence and history of mosquito-borne disease in the Philippines may lead to new conversations insights into the influence of mosquitos on the outcomes of historical, social and political events. The introduction of Aedes aegypti into the Philippines in the late 19th century seems to coincide with the Spanish-American War and the concession of the Philippines to the United States leading to the Philippine-American War in late 1890s and early 1900s. Texts
such as Warwick Anderson’s *Colonial Pathologies* (2006) help provide accounts and a context of American imperialism and the impact of tropical military hygiene on creating country-wide public health interventions. Other researchers, including Makenzie et al. 2004, suggest a connection between WWII and the introduction, emergence and proliferation of dengue and dengue hemorrhagic fever in Japanese and American troops stationed in the Philippines. The time period of WWII further coincides with military hygiene programs in the Philippines such as the “Malaria Control in War Areas” program, 1942 to 1945, as cited in *Colonial Pathologies* (Anderson, 2006). Makenzie and Anderson briefly mention the attempted control and ultimate failure of mosquito eradication programs, which were followed by cyclical spikes of dengue and malaria in subsequent decades. As stated in *Colonial Pathologies*: “On occasion, war, famine or development could whip it [malaria] up into major epidemics,” as seen in the post-Philippine American War epidemics in 1903 and 1906 and again in the 1930s (Anderson, 2006). While I suggest that dengue was first introduced into the Philippines around the turn of the century, there is a consensus in public health literature that the emergence of the most deadly form of dengue, dengue hemorrhagic fever arose in the Philippines and Thailand in the 1940s and 1950s (WHO). Whether or not there are real causal implications of US intervention and dengue emergence in the Philippines, the co-occurrences of these factors warrant further investigation.

In the time since WWII, the Philippines has seen spikes of dengue and malaria. Today, the nation is facing other complex issues like those articulated by B.E Johansen in his 2003 book, *Indigenous Peoples and Environmental Issues*. Johansen highlights the existence of a long-time struggle to combat illegal logging in regions like the Cagayan Valley and on the Island of Mindanao home to indigenous groups. Other contemporary studies such as Reboredo (2013), have found that illegal logging is an underestimated and under-studied issue that undermines
governance, especially in Luzon, Negros and Mindanao. While Reboredo (2013) does not mention the potential public health and zoonotic disease implications for illegal logging in these regions, Philippine health organizations have indicated that there is a co-occurrence and disproportionate number of cases of malaria and dengue in those regions (*Eliminating malaria in the Philippines*, 2012).

1.3: Mosquitoes and dengue in the early Philippines

“Among the chief nuisances in the Philippines are mosquitoes and ants. The ordinary bed is a hemp mat, without sheets, but never without ample mosquito nets, in the absence of which sleep would be banished,” (Lala, 1898).

Both *Aedes aegypti* and dengue are found inland near coasts and ports (Smith, 1956). The exact dates of the introduction of *Aedes aegypti* and dengue are unknown, however the first records of the circulation of dengue in the Philippines are among accounts from military hygiene records after the Philippine-American War recorded in 1903 among U.S. soldiers stationed in bases in Manila. Siler provides a vivid description of some of the symptoms of infection: “Typical cases are characterized by sudden onset with physical weakness, headache, postorbital pain and soreness, flushing of the face, suffusion of the eyes, anorexia with loss of the sense of taste, backache, pain in the bones and joints, marked prostration, mental depression, and a general feeling of wretchedness.”

In Siler 1926, studies of dengue are limited by the study of the manifestations of the disease as it pertained to foreigners, primarily American troops and those in the Philippine military. This text emphasizes (however incorrectly) that the pathogen is often not deadly to native Filipinos and speculates that they may have a form of immunity to it and are therefore not subjects of study.
There is no information about the early dynamics of dengue in native Filipino populations. However, the rationale given by Siler 1926 is flawed, as there must have been rampant infection in native Filipino populations in order for the pathogen to flare and infect new military personnel. According to Siler, “The general opinion of physicians and of old residents is that when an American or European first arrives in the Philippines he will almost certainly contract dengue within his first year and then suffer subsequent attacks of diminishing severity.” This account of the consensus around dengue and the emphasis of repeated attacks may indicate that at the time of publication, there were already more than one serotype of dengue circulating in human populations in Manila. Each of the four known serotypes confer lifelong acquired immunity to the individual for the specific type after infection, however the risk of dengue hemorrhagic fever increases with each infection, (WHO: Dengue). This early account of multiple cases of dengue in new individuals may indicate that dengue was introduced into some Filipino populations and continued to circulate, particularly in those around Manila in the early 1900s.

The key US military forts in the early 1900s depicted in the study of dengue include the Post of Manila, Fort William McKinley, Fort Mills and Camp Nichols, all located in or on the outskirts of Manila; Camp Stotsenburg situated in Luzon Island north of Manila; Camp John Hay located in the northern mountains of Luzon; and Pettit Barracks, situated in Zamboanga, Mindanao. Another prominent base, Camp Hay, was excluded from dengue analysis because at the time it was situated at an elevation of 1,500 meters and there were no reports of known cases there. Siler’s 1926 accounts emphasize a few important factors surrounding early dengue outbreaks: Manila was an epicenter and breeding ground for Ae. aegypti and a base for the majority of military personnel. This further supports the fact that dengue was likely a newly-introduced pathogen at the time, as accounts of Camp Stotsenburg and other military camps far from ports...
and the city of Manila were often dengue free. But Siler speculates that these differences may also be due to varying vector control efforts (Figure 4).

![Figure 4 Dengue Rates in American Military Bases in Philippines 1922-1924, American Troops only (Siler, 1926)](image)

Regional ecology and climate cycles play key roles in mosquito-borne disease dynamics. Peaks in cases of dengue correlate heavily to the onset of the rainy season, which in the Philippines occurs from June to November, with the hot/dry season preceding it in the March to May months. As rainwater collects in various receptacles it creates new, temporary breeding habitat for mosquitoes. The amount of rain also affects larval populations. “The rainfall in Manila from June to September is uniformly high, and environmental conditions for the breeding of mosquitoes in general are ideal. It is during these months however, that typhoons usually and most frequently occur, the rainfall is heavy, and at times is continuous for a week or so. The typhoon weather is, in some respects, not conducive to the multiplication of mosquitoes as the eggs and larvae are carried by the heavy washing rains” (Siler, 1926).
Siler, 1926 provides candid accounts of the day-to-day habitat of *Aedes aegypti*. “In Manila, many of the buildings are of a permanent type of construction with the inevitable roof gutter that becomes clogged or has depressions here and there that will hold collections of rain water. The roof gutters, together with collections of tin cans, broken bottles etc., on the premises, and standing water in containers inside houses result in the breeding of immense numbers of *Aedes aegypti* mosquitoes” (Siler, 1926). The “buildings of a permanent type construction” with rain gutters in Manila, akin to those in (Figure 5). These buildings are of a distinctly western construction and differ from accounts of indigenous buildings and construction provided by both Siler and by Philippine native Ramon Rayes Lala in his book *The Philippine Islands* 1898, as in (Figure 6). These constructions and the accounts of their influence on increasing mosquito populations are often overlooked and is evidence of the theme of unintentional implications that result from the imposition of colonial architecture and customs on Filipino peoples. “In the provinces the majority of the buildings are constructed of nipa with thatched roofs and without roof gutters, the population is more stable, there are comparatively few non-immunes (Americans and Europeans), and it is probable that *Aedes aegypti* are constantly present in smaller numbers than in the case in Manila. […] Ordinary observation in Manila shows that dengue is a neighborhood disease” (Siler, 1926).
Section 2: Creating the Conditions of Epidemics in the Philippines

The Philippines as a keystone region and a likely representation of the further westward expansion and biological invasion of mosquitoes and mosquito-borne disease into Southeast Asia and the Indian Ocean. Investigating how each of the four conditions of mosquito-borne disease were created in the Philippines surrounding the turn of the century is necessary for understanding...
future prevention. I detail how location and the history of trade, sugar and war spurred social, ecological and human geographic change in the Philippines under Spanish and American imperial regimes.

2.1: The Philippines – On Periphery of the Indian Ocean world

The Philippines stands as a gateway, a portal bridging two oceanic worlds. To the east lies the Indian Ocean and the vast and ancient maritime trade routes connecting neighbors in East Africa, India, China and the Southeast Asian archipelagoes coasting aboard dhows with monsoon winds. To the west the Pacific, a vast aquatic emptiness enclosing lonely Hawaiian Islands and demanding a turbulent five-month sail to the Americas. From the time the Philippines was permanently inhabited some 30,000 years ago, its demographics have been mixed, comprised of indigenous and multi-ethnic and multi-originated peoples, occupying islands as kingdoms and made up of Malay, Tagalog, Mohammedan, and Negrito as well as Chinese pirates, Japanese martyrs, Islamic traders and Spanish Mestizos (Lala, 1898).

The location of the islands proved a coveted asset. Before the Spanish, the “Barangay” was the typical community in the whole archipelago. It was a basic political and economic unit independent of similar others. Each embraced a few hundred people and a small territory and each was headed by the chieftain called the “rajah” or “datu” (Guerrerro, 1970).

The colonization of the Philippines in the early 1500’s by the warring Portuguese, Dutch and Spanish, speaks to the islands’ abundant spice and natural resources as well as strategic location as a bridge between eastern and western worlds. The Spanish colonized the Philippine islands, beginning with Mindanao in 1521, and establishing the Manila Galleons by 1552 (Lala, 1898). Spanish colonial rule worked to limit and control Philippine trade with merchants from the East...
Indian Ocean worlds and extorted raw materials from Filipinos for trade with Chinese junks for silks and luxury textiles to be shipped to Spain by way of Mexico. “Trade under Spanish colonial policy was rigid, ‘putting to death any alien merchant that ventured into one of her ports” (Lala, 1898).

“In the mid-1560s, a Spanish expedition under the command of Miguel Lopez Legaspi sailed from Mexico and invaded the Philippines. Manila, with trading connections all over the Far East, was to be the center, the Havana, of the Spanish Orient” (Crosby, 1986). By the 1600s, global travel had increased and developed so that even a regular citizen could make a trip on the boats of merchants from Spain to America, travel across Mexico to Acapulco and catch the annual Manila Galleon to Manila, for travel to Japan, on to Macau and then sail to Goa in India (Crosby, 1986; Figure 7).

*Figure 7 Trade Routes and Cultural Influences of the Philippine Islands 900-1500 http://malacanang.gov.ph/75822-ph-trades-routes-infographic/
The Philippines was treated as an appendage of the intermediate colony of Mexico. Filipinos paid their taxes in the form of goods and raw materials which were then traded for Chinese luxury goods. The single galleon that traveled across the pacific between Manila and Acapulco from 1552 until 1811 always contained 1500 barrels of Chinese goods, a representation of the Philippine contribution to Spain (Lala, 1898).

2.2: Sugar – Catalyst of Environmental Change

The cultivation of sugar has long been a water-intensive process subject to pests and inefficiencies. Early Indian sugar cane was often grown in protective enclosures near river banks or on the edge of forests (Gopal, 1964). However, history has largely ignored the immense ecological change and destabilization caused by the deforestation and conversion of land to accommodate large plantations. This mass alteration of land became a turning point in Indian Ocean and Philippine history and helped spark a chain of events that affected not only the movement and geography of people, but also of mosquitos and ultimately mosquito borne-disease. In this section I detail how ecological and environmental history shifted with sugar. I recast sugar as a driver of change that has had unforeseen implications that have reverberated through time, into the present, demonstrating that societies are often dictated by and closely linked to their environmental histories.

Sugar cane is composed of a complex of six perennial grasses in the genus Saccharum which consist of both wild and cultivated varieties (Sharpe, 1). The species S. robustum and S. officinarum are varieties that likely originated in and are found around the river banks of New Guinea and some of its adjacent islands, whereas S. barbati and S. sinsese are found and likely originated in India (Purseglove, 1979). Early peoples of the Philippine Islands chewed the cane as a treat and means of “assuaging hunger, mothers employed it as a pacifier for babies, and
children ate it mixed with rice” (Larkin, 1993). *Saccharum violaceum* also found in Malaysia and Polynesia were the central varieties of sugar found in the Philippines, the yellow variety grown in Pampanga (Luzon) and the purple variety grown in Panay and Negros (Lala, 1898).

Sugar cane’s history in the Philippines spans its early chewed, ethnobotanical and medicinal origins to its mass-cultivation and mechanical refinement on Spanish haciendas. The story culminates in the crop’s contemporary cultivation in large, more mechanized plantations (Figure 8). While current discourse on the origins and cultivation of sugar cane focus predominantly on development, production, and sugar’s role in the creation of plantation economies, there is little discourse on its role in ecological destabilization and facilitation of mosquito invasions (Galloway; Hawaiian Sugar Planters’ Association; Larkin; Rutten).


**Figure 8 Sugar Estates on Southern Philippines**

Like other indicators of change in the Indian Ocean World, the history of sugar cane production follows a global trend of environmental change and ecological imperialism in the Philippine
Archipelago, that is described in detail in Alfred Crosby’s *Ecological Imperialism: The Biological Expansion of Europe 900-1900*. In the Philippines “commercial sugar became intrinsically associated with the colonial experience” (Larkin, 1993). According to Galloway (1989), “the ability to make crystalline sugar led to an increase in demand which stimulated an extension in the area planted to sugar cane, and its cultivation as a commercial crop in the Ganges valley and greater Indian Ocean was ‘widespread’” (Galloway, 1989). The spread of the practice and refinement of sugar cane around the maritime routes of the Indian Ocean has had significant impacts on people of island nations. “Although natives to the [Philippine] archipelago cultivated and chewed sugar cane before the coming of the Spaniards, the milling, consumption, and shipping abroad [to Europe and the Americas] of brown sugar followed in the wake of the sixteenth-century Iberian conquest, when Catholic friars and Chinese entrepreneurs introduced the technology and created the first middlemen networks” (Larkin, 1993). During the first 150 years of Spanish colonization, the exportation of sugar was only a small factor in the colonial economy, however as regional sugar plantations grew, “areas near Manila started to specialize in the manufacture of Pilon, or coarse, brown, molded sugar, and native farmers became linked to international commerce through a network of foreign and colonial entrepreneurs” (Larkin, 1993).

By the early 19th century, the first real plantations in the archipelago began to appear, first in central Luzon and later in Negros and other islands of the central Philippines (Larkin, 1993; Figure 9). From cultivation to production, sugar cane requires the aggregation of a large labor force. As “cane begins to deteriorate immediately upon being cut, it must be delivered rapidly and in proper amounts to keep mills operating efficiently. The harvest season is therefore very busy, and only a large well-disciplined labor force capable of toiling in the tropical heat can meet its demands” (Larkin, 1993). The shift in geographic distribution is evidenced by Lala’s
accounts, *Plantation life is the industrial unit of the Islands*, and large plantations having 500 to 600 employees (Lala, 1898). Populations in the Philippines began to aggregate in mass as they hadn’t before, making them susceptible to zoonotic epidemics. In addition to creating a large low-wage labor force and densely-populated human living situations, “sugar growers led the way to a transformation of the Philippine countryside as they converted deep jungle into extensive sugar haciendas, and major portions of western Negros and northern Pampanga felt this impact” (Larkin, 1993). Sugar requires the clearing of land, and the use of timber for refinement, to power mill machinery. The need for land and fuel drove deforestation. In addition to deforestation, plantations built on hilly land likely caused erosion and depleted soils. The shift of natural water cycles by forest loss brought the need for irrigation. Both agricultural irrigation and deforestation have been linked to the increase in mosquito populations (Jaleta et al 2013; McNeill, 2010).

*Figure 9 Production of Sugar on Philippines 1910, (Nesom and Walker, 1912)*
In addition to irrigation, water-intensive techniques were often used in the harvesting process of sugar cane—fluming, a method of harvesting cane by a water-fed field conveyor system, that created more sunlit artificial pools of standing water — prime habitat for mosquitoes. (Hawaiian Sugar Planters’ Association; Jaleta et al 2013). Deforestation and irrigation are found to be major factors in an increase in the prevalence of malaria and *Anopheles* mosquitoes (Jaleta et al. 2013). The conversion of land in most cases leads to changes in soil nutrients and the penetration of light to what was once forest floor increases ground temperatures, which leads to increases in the bioactivity or biting rate of mosquitoes (Vittor et al 2006; Vittor et al 2009). The changes in local ecology and the reduction of forests and plant biodiversity may also reduce the habitat of key mosquito predators and may reduce the normal biological control patterns for mosquito populations (Taber and Smithwick 2015).

It is not enough to simply contextualize the domestication and mass cultivation of sugar cane. Larger connections need to be drawn from these events of physical change to the Indian Ocean World. Sugar-cane plantations not only changed the geography of people in the Indian Ocean, drawing in outsiders carrying foreign pathogens and disease, it also caused the physical alteration of landscapes, making the land more susceptible to mosquito invasions. Thus the Philippines was made more susceptible to mosquito-borne disease epidemics.

The rise of the global consumption of sugar coincided with and arguably aided the rise of European imperialism. It was a key driver for the creation of large-scale sugar cane plantations in the Indian Ocean World. The growth of Philippine sugar production meant the further reduction of food self-sufficiency and food security. Filipinos became more dependent on, and yoked to, the resource extractive economy as rice planting decreased and large quantities had to be imported from Siam [Thailand], Burma [Myanmar] and China (Lala, 1899).
2.3: Conveyance by Vessels: Medical Records 1904

Early naval records point to the passive transportation of mosquito vectors aboard both steam and sailing ships. Adult mosquitoes were frequently found among the cargo of steamships and were often found breeding aboard containers on sailing ships. “It seems fair to say that they [mosquitoes] are conveyed by vessels in small number far oftener than the reports we have would lead us to believe. A negative statement of the crew is of little moment” (Medical Record, 1904). For instance, a port inspector found Stegimyia (Ae. aegypti) on two fruit vessels in New Orleans in 1892, “they have also been found at a Ship Island Quarantine aboard three vessels sailing from Vera Cruz” (Medical Record, 1904). It is important to note here that Aedes aegypti populations have long been established in Vera Cruz, a region about 700 km from Acapulco, Mexico, and while there is little information about mosquito vectors in early Acapulco, the ecology of the region is similar to that found in Veracruz and it is likely that Ae. aegypti were also established in urban centers there. The 1904 medical record gives significant accounts and rare accounts of mosquitoes found breeding aboard ships: “At a Tampa Bay Quarantine Station, aboard one vessel sailing from Buenos Ayres, they had bred aboard in the water tanks, as had those in one of the previous cases. At the Savannah Quarantine they were found aboard two vessels from Cape Town (direct) and Havana respectively both sailing vessels, and aboard both “water barrels were alive with wrigglers” which developed into Stegimyia [Aedes aegypti]” (Medical Record, 1904).

It is clear that mosquitoes can survive and thrive aboard fast steamships and their slower predecessors, sailing ships. The conditions on sail boats and ships need not be constant throughout the long journey, as Aedes aegypti lay their eggs on the sides of containers just above the water line and their eggs can then survive dried for a year and when rehydrated by water will
hatch and develop (CDC-Dengue). The nature of open water cisterns and fresh water containers aboard sailing ships, including Spanish ships, like those that made the trans-Pacific Manila Galleon voyages, likely carried mosquitoes from Acapulco to Philippine ports, helping to establish small and early populations of mosquitoes in their over-250 year circulation.

While I have found no accounts of mosquitoes breeding on ships introduced into Manila, the probability that it happened is great as there are other accounts of mosquitoes being introduced from Mexico to Hawaii. “I think however that it is unquestionably true that Stegimyia was thus introduced into the Hawaiian Islands, where it is now abundant and widely distributed, these islands being free from mosquitos until 1826, when they were introduced by a vessel from San Blas, Mexico” (Medical Record, 1904). It is important to note that San Blas is located on the west coast of Mexico, touching the Pacific Ocean and is situated north of Acapulco. This is a rare and early account of mosquitoes in this geographic location, as many historical accounts focus of the east coast of the American and the trans- and intra-Atlantic circulation of mosquitoes and disease. The Hawaii account gives further validity to my argument of the early trans-Pacific transportation of mosquitoes into the Philippines that was then followed by epidemics of dengue.

In the case of the Philippines, it is important to reiterate that the average Manila Galleon voyage took approximately five months to cross the Pacific Ocean. There were more than 250 voyages, or opportunities for mosquitoes to breed or be introduced aboard ships from the New World. It is likely that the Aedes aegypti arrived decades before the dengue pathogen came to the Philippines. The first record of dengue fever in the Caribbean can be traced to 1826, while the first record of Yellow Fever, the pathogen carried by the same mosquito vector dates back to 1648 and suggests that Aedes aegypti has long been established in the New World. It is well
documented in McNiell’s *Mosquito Empires* that the colonization of *Aedes aegypti* in the New World was a consequence of the mass transport of slaves on ships in the trans-Atlantic slave trade. The trans-Atlantic slave trade began in the late 15th century and the length of voyages took anywhere from one to six months, but differed from the Manila Galleons in that it carried densely packed human cargo as opposed to Chinese luxury goods and merchants (Carter, 1931). While both dengue and yellow fever were well established in the New World before being introduced into the Pacific and Indian Oceans, yellow fever has never been recorded in Philippines. This is said to be a great public health mystery of the time (Powell et al. 2013).

One reason for the delay in the introduction of dengue in Philippines may have been the length of early trans-Pacific voyages. Galleons made five month-long journeys across the Pacific using monsoon winds. The slow transport and sparsely populated ships likely were barriers to a continual transmission of pathogen to person; five months would have been ample time for a small crew to either acquire immunity or die before reaching the islands. Either the pathogen would have been exhausted in finding new non-immune human hosts or the virulent mosquitoes would have reproduced and died before the end of the voyage (Carter, 1931). This hypothesis is substantiated by the pathology of yellow fever given by the CDC, as “people infected with yellow fever virus are infectious to mosquitoes (referred to as being "viremic") shortly before the onset of fever and up to five days after onset” (CDC| Yellow fever, 2016).

The mosquitoes established populations first in urban port cities, like Manila, due to ship transport and available habitat exacerbated by the importation of architecture conducive to creating mosquito breeding habitats under colonial rule. Later, as faster steamships began to replace sailing ships in the mid and late 1800s, it is probable that the dengue pathogen was able
to survive the voyage circulating in people or soldiers, landing in Manila and beginning the cycle of human-mosquito transmission in the Philippines.

2.4: Estates, Urbanization and the Translocation of Architecture

Aside from ships, the importation of western customs and architecture made the Philippines susceptible to the colonization of *Aedes aegypti*. There are accounts of the species breeding in a variety of habitats and containers of western design, from clogged rain gutters in Manila to fire barrels near ports and air bases and even among permeant flower vases built into cemetery tombs. The imported mosquitoes are opportunistic colonizers (Siler, 1926; Johensen, 1966; Schultz, 1989; Figure 10. The distinct accounts of mosquitoes breeding in cement vases attached to tombs are ominous signifiers of the unintended consequences of European and American influence and expansion in the Philippines. “There are several large cemeteries within Manila and its surrounding suburbs. The tombs within these cemeteries are always above ground and sometimes multilayered. Cement vases capable of holding water are often attached to the tombs.” (Schultz, 1989)Early photos of Manila from the late 1800s and early 1900s depict colonial estates and state government buildings that are in stark contrast to imagery of villages with homes constructed of nipa palms and long grasses from the same period (Nesom and Walker, 1912).
The colonization of *Ae. aegypti* across the archipelago followed the growth and expansion of urban centers. Johnsen (1966) recorded a drastic shift in the species composition of mosquitoes over a period of five years that bred in fire barrels within a Negrito village outside of a northern military base. At first, the main species were almost entirely *Aedes albopictus*, a less domesticated and forest-dwelling species of *Aedes* mosquitoes. But within a few years’ time, the composition of mosquitoes found breeding in fire barrels had almost completely shifted to *Aedes aegypti* the most efficient and virulent vector. Further, *Aedes aegypti* is known to be one of the first species to recolonize regions after natural disasters and make use of manmade containers (Brown et al. 2014).

### 2.5: The Spanish American and Philippine American War

The period between 1890 and 1910 was a critical time for dengue, representing a shift in colonial regime in the Philippines through the Spanish-American and Philippine-American wars. It was a period of social instability, marking the end of Spanish colonial rule and the beginning of U.S.
imperialism. Both Spanish and American military personnel traveled rapidly and en-masse from regions the Americas to the Philippines. While the majority of American soldiers, some 75,000, traveled through Presidio (the military base in San Francisco) there are records of ships and crews moving from the Caribbean and Hawaii to Manila aboard the USS Charleston and the USS Newport (Russell, 1899; Figure 11). Soldiers reached first the ports and military bases in Manila and then spread to various bases across the archipelago. There is evidence of dengue circulating among American military forces in epidemic proportions in Cuba in 1897 (Ehrenkranz et al. 1971 and Gibbons et al. 2012).

It is likely, given 1902 accounts of mass transmission of dengue among U.S. soldiers stationed at Manila military bases, that the soldiers traveling in large numbers across the Pacific were likely passive carriers of the dengue pathogen into Philippine ports (Siler, 1926; Figure 12). The mass and rapid movement of both infected and uninfected non-immune people on naval steamships
from the Americas created another condition of mosquito-borne disease. It is likely that the war brought not only soldiers, but also diseases such as dengue into the Philippines.

![Image](image_url)

*Figure 12 U.S.S. Charelston Steamship Spanish and Philippine American war, Russell 1899*

Upon Spain’s concession of the Philippines to the United States for a sum of $20 million, U.S. soldiers were shipped in to quell Filipino resistance (Gibbons et al. 2012). The Philippine American War is documented as officially occurring between 1899 and 1902. However, some sources point to efforts of resistance and guerrilla warfare lasting well into 1913 (US Office of the Historian, 2016; Guerrera, 1970). “Before the Philippine American War was decisively won by U.S. Imperialism in 1902, 126,468 U.S. troops had been unleashed against the 7,000,000 Filipino people” (Guerrero, 1970). By the end of the war, at least 4,000 U.S. soldiers were killed and close to 200,000 Filipino combatants and civilians were killed by a combination of violence, famine and disease (Guerrero, 1970; US Office of the Historian, 2016). War is often marked by social instability — hunger, unreliable infrastructure and mass casualties. In the Philippines, these factors made people vulnerable to the contraction of disease, particularly dengue. The four
basic conditions of epidemics of mosquito borne-disease were all likely present in Manila during and in the wake of the Philippine American war.

The war likely increased urban habitat for mosquitoes, leaving broken structures and refuse that created ample, shallow, sunlit pools of water and artificial containers that increased not only the incidence of *Aedes aegypti*, but also of *Anopheles* mosquitoes. Greater mosquito populations likely explains the increased incidence of the transmission of dengue and malaria among both military and civilian populations (Colonial Pathologies, 2006). Gurrera (1970) wrote that “the depredations of the US aggressor troops in the Filipino-American War had resulted in various kinds of pestilence and epidemics, especially cholera and malaria,” which threatened the health of the soldiers and prompted the first efforts of tropical military hygiene and mosquito control (Siler, 1926; US Office of the Historian, 2016).

### 2.6: American Colonization

By 1903, the U.S. government passed several laws to combat guerrilla warfare, as well as to change the geography of people in the Philippines. The Sedition Law of 1901, the Brigandage Act of 1902, and the Reconcentration Act of 1903 were passed to sanction military operations against the people as mere police operations against “common criminals.” Philippine patriots were labeled bandits and people in extensive areas were herded into military camps in order to separate them from the patriot guerrillas (Guerrera, 1970). “I have also been privileged to see the effects of military reconcentration of the civil population in war times in Cuba and the Philippine Islands, and I think that there was more evidence of relative starvation among the children of Cuba than in Serbia or the Philippines. In the Philippines it must be remembered that concentration was administered by Americans, and every possible precaution to prevent starvation was carefully carried out” (Jackson, 1916). The U.S. military at times burned villages...
in effort to reconcentrate people into military camps and urban centers (US Office of the Historian, 2016). In addition to changing human geography and the concentrations of Filipinos to favor military camps, “after Philippine revolutionary forces had been defeated, U.S. imperialism drew from the country an increasing quantity of such commercial crops as sugar, coconut, hemp, and tobacco, in addition to other raw materials as logs and mineral ores. Sugar centrals, coconut oil refineries, and rope factories were built. The hacienda system of agriculture was further encouraged and reached its full development under the U.S. colonial regime” (Guerrero, 1970).

The reconcentration of people had severe implications in terms of susceptibility to mosquito borne diseases like dengue, malaria and cholera. The *Ae. aegypti* mosquito is highly efficient at transmitting disease, particularly in warm temperatures and is known to bite people multiple times and in rapid succession (Vittor, 2006). The unintended implications of the reconcentration of people into US military camps can be seen in the first major dengue epidemic recorded in the Philippines, which occurred in 1906 in Fort McKinley, a U.S. military base located on a low lying site in Manila (Gibbons et al. 2012).

In addition to the passage of laws that forced geographic population shifts, American colonial rule resulted in the development of the sugar industry, which grew to be one of the key raw materials exported from the Philippines to the U.S. “During the first three decades of U.S. imperialist rule, agricultural production for export was expanded more rapidly than ever before. By 1932, more than 99 percent of sugar exports was going to the United States” (Gurrera, 1970). The increased plantation production and forced expansion into uncharted lands (Negros) caused more rapid deforestation and opened new land to urbanization and colonization by mosquitoes. As sugar production is a labor intensive process, the growth in plantations spurred another shift in human geography. The methods employed in the further expansion of sugar cane included that
of slashing and burning, a method linked to the increase in mosquito vectors and malaria in the Americas (Larkin, 1993). “New lands planted to sugar cane in the Philippines are usually covered with a heavy growth of dense, tall grasses, sometimes a scattered growth of scrub brush and occasionally tropical forest” (Nesom and Walker, 1912). Resource and raw materials extraction increased in the Philippines under American colonization, and as the trade barriers set by the Spanish were lifted, opening the Philippines to the forces of free trade. Finished goods were imported into the Philippines and their use become prolific, undercutting local handicraft industries, which further entrenched the Philippines into a raw materials and extractive resource economy. Mosquitoes and people invaded and settled the islands bringing cyclical epidemics of dengue and setting the stage for the rise of dengue hemorrhagic fever.

**2.7: WWII and Dengue Hemorrhagic Fever**

Upon dengue’s introduction into the Philippines, the pathogen emerged and reemerged in cyclic epidemics starting around the turn of the century. WWII and the Japanese occupation of the Philippines was a new cause of social instability and environmental change. After the war, mosquito control efforts and the use of DDT, an organochlorine insecticide, increased and waned with dengue epidemics but were likely significant contributing factors in the emergence of dengue hemorrhagic fever, the most deadly form of dengue.

There are numerous accounts of military hygiene efforts and attempts to maintain control of mosquito populations and mosquito borne disease by periodically dousing regions of the Philippines, particularly military bases around Manila, with insecticides throughout the 20th century. In 1944-1945, epidemics of dengue occurred only sporadically, likely due to extensive use of aerial spraying of DDT and kerosene on populated areas of Luzon from the beginning of the reoccupation (Gibbons et al. 2012; McCoy, 1964). It is well known in contemporary
biological literature that the overuse or misuse of insecticides and drugs may spur local vectors and pathogens to develop forms of resistance, making the chemicals less potent and effective (Marcombe et al 2012; Karyana et al 2008). DDT is an organochlorine insecticide, now banned by the EPA and many western nations, that was widely promoted and used in the period after WWII and has been linked to increased incidences of breast cancer, male infertility, miscarriages, liver and kidney damage in humans and the thinning of eggshells in birds (Pesticide Action Network, 2016).

The 1946 Treaty of Manila marked the end of official U.S. colonization of the Philippines, and although the U.S. continues to maintain close ties to the nation, this period marked a slackening of mosquito vector control efforts. The post-war period through 1970 included development of plans for the eradication of dengue in the Americas and globally, however the effort deteriorated with the lower incidence of dengue, and mosquitoes began to develop a resistance to DDT and other organochlorine insecticides (Brathwaite Dick, 2012; Figure 13). “During the war, both the viruses and the principal urban mosquito vector became widely distributed in the urban centers of southeast Asia. The economic development and massive unplanned urbanization that followed the conflict, combined with lack of mosquito control, resulted in increased epidemic activity and the emergence of DHF in that region in the 1950s and 1960s. A similar pattern of unplanned urbanization and lack of mosquito control occurred in the Pacific and the American tropics in the 1970s and 1980s” (Makenzie et al 2004).
During the rainy season in 1954, pediatricians in Manila, Luzon, observed a number of serious and often fatal cases of hemorrhagic febrile disease. It was described as a new disease and was named the Philippine hemorrhagic fever. During the rainy season of 1956, a large epidemic occurred in Manila with over 750 cases and about 75 fatalities. (Hammon et al. 1960). Philippine hemorrhagic fever was renamed dengue hemorrhagic fever (DHF) as more cases were identified in Thailand and the Philippines. Dengue hemorrhagic fever has now spread throughout and is found in the tropical and sub-tropical regions of the world. The recent pathogen was likely carried to new populations by humans moving rapidly on planes or steamships around the world. DHF spread both east and west from S.E Asia only decades after dengue was likely first introduced into the archipelago. While the social and historical period around the emergence and spread of DHF is well documented and correlated to the period after WWII and failed mosquito eradication efforts and military hygiene, the connections between the this history, human caused conditions, and the emergence of new pathogens are not explicit in Public Health literature and discourse and again, work to frame the emergence of DHF as coincidental as opposed to consequential (WPRO, 2016; CDC Dengue, 2016; WHO Dengue; 2016).
Section 3: Contemporary Implications, Conclusions and Future Directions

3.1: Contemporary Implications

The 21st century emergence of drug and insecticide resistant vectors and pathogens is further evidence for the need of historical contextualization and a refinement in the approaches of public health. “Dengue fever is an old disease, but in the past 25 years there has been a marked global emergence and re-emergence of epidemic dengue, with more frequent and larger epidemics associated with more severe disease” (Makenzie et al 2004). Human actions, in addition to causing the conditions for mosquito borne-epidemics and biological invasion, are key drivers for recent adaptations of Ae. aegypti and the arboviruses it transmits (Brown et al 2013; Ramasamy and Surendran 2016; Marcombe et al 2012). Both historical accounts and contemporary ecological research point to an evolutionary arms race occurring between humans and anthropophagic, or human loving, mosquitoes. Research published within the past five years suggests that mosquitoes are adapting to vector control measures more rapidly than previously thought. Reports also suggest a rapid development and spread of organochloride, organophosphate and pyrethroid insecticide resistance among mosquito populations (Marcobe et al 2012). Investigators have also found Ae. aegypti, a freshwater mosquito, breeding in brackish (salty) water in coastal regions in areas of Sri Lanka with extensive mosquito control programs (Ramasamy and Surendran 2016). Research suggests that the development of insecticide resistance and adaption to non-conventional or new breeding locations, are not random or isolated occurrences (Ramasamy and Surendran 2016). In fact, studies by both Brown et al 2013 and Ramasamy and Surendran 2016 suggest that human actions, particularly those surrounding mosquito vector control, agriculture, and urbanization are actively driving the adaptation of Ae. aegypti and other mosquito vectors. In Martinique, the exposure of mosquitoes to large amounts
of pesticides on sugar plantations in association with urbanization is thought to have driven a
genetic selection of genes that increase their tolerance to pesticides (Marcombe et al 2012). The
Philippines, still a major producer of sugar and raw materials, like Martinique, may prove again
to be a vulnerable location for the development and spread of evolved vectors and pathogens.

While human action continues to drive mosquito adaptation, pathogens are becoming more
difficult to eliminate. The approval of the use of the new dengue vaccine, CYD-TDV, in the
Philippines is proving controversial due to potential negative implications for susceptibility to
zika virus. There seems to be contention in recent literature over the vaccine as some researchers
suggest that it may make children under 5 more vulnerable to severe cases of dengue upon
infection with more than one serotype; they point to incidences of higher rates of hospitalization
in vaccinated children (Halstead and Russell, 2016). The manufacturer of the CYD-TDV
vaccine, Sanofi Pasteur, denies these claims, although some researchers point to a potential
conflict of interest as the company has reportedly invested $2 billion in the vaccine’s
development. Other researchers suggest that the vaccine, approved for use by the WHO in April,
2016, may have significant implications for zika virus, arguing that pre-existing dengue
immunity may enhance zika infections and increase the severity of the disease (Paul et al 2016).
Researchers on both sides of the argument however agree that there is not enough information
about the interactions of the vaccine to make definitive claims.

3.2 – Concluding Reiterations and Remarks

To reiterate, my argument — like the problem of mosquito-borne disease — is multifaceted. I
argue that the contemporary global distribution of the mosquito vector Aedes aegypti, as well as
epidemics of dengue, are a product of colonial legacy and European expansion into and among
tropical worlds. Contextualizing and historically situating Aedes aegypti and dengue in the Asia
Pacific is necessary and essential to understanding large-scale spatial and temporal patterns and the conditions that create or facilitate mosquito-borne epidemics.

By investigating the intersections of environmental history, colonial and military legacy, and dengue in the Philippines in the 19th and 20th century, we are able to recast epidemics of mosquito-borne disease as unintended consequences of human action as opposed to random and unfortunate events. I demonstrate this by investigating how the four main conditions of dengue epidemics were met in the Philippines at this period: 1) new mosquitoes were introduced, 2) human populations and geography were shifted and condensed, 3) mosquito populations grew and thrived with translocated architecture and the growth in sugar production, and finally 4) the onset of war likely introduced the dengue pathogen with the importation of American and Spanish soldiers, completing the cycle of disease transmission (Figure 14).

Figure 14 Spanish Soldiers held captive by Americans, 1898 http://www.philippine-history.org/picture-old-manila26.htm
I argue that the exclusion of the aforementioned history from the discourse of the WHO and CDC, in addition to the failure to emphasize the significance of land use and deforestation in relation to mosquitoes and dengue, has several significant implications. It is an act of erasure of not only the legacy and reverberating impacts of colonial regimes, but also of Filipino people and of peoples of the tropics. It is a method of paternalism, driving both historic military hygiene efforts and contemporary public health interventions, which attempt to regulate conduct of those under its control [people of tropical worlds] in matters affecting them as individuals as well as in their relations to authority and to each other. It is a means of concealing influence and masking the real motivations of these organizations, which I suggest are and have historically been tentacles of Western Imperialism. Finally, it allows industries, nations and powers responsible for mass land alteration and deforestation to continue to externalize the costs of man-made vector-borne disease on human health and to persist in the creation of conditions of disease.

The lack of critique further perpetuates the problematic notions of colonial regimes as bringers of positive development and improvement to the condition of local peoples, when in fact they translocated pests, pathogens, technology and altered environments that worked to plague, sicken and under-develop the subjected peoples.

Warwick Anderson’s book, Colonial Pathologies: American Tropical Medicine, Race and Hygiene in the Philippines, best exemplifies how early public health efforts with roots in military hygiene worked in tandem with development efforts to civilize and ultimately exploit, subject and cleanse Filipino people in the early 20th century. Anderson emphasizes that most of the early military tropical hygiene efforts in the Philippines were based in notions of biological determinism, the idea that race and physical features are inherently linked to intelligence and ability; early hygienists used the ‘racial factor’ to explain malaria outbreaks in white soldiers...
Asymptomatic Filipino soldiers and children were almost always cast as the inherent unhygienic carriers, the “source of fatal infection to white men” and European settlers (Anderson, 2006). Early military hygiene efforts in the Philippines dealt largely with malaria, records from 1903 and 1904 indicate that officers often found mosquito vector control useless and often recommended dosing whole Filipino villages with quinine, an early antimalarial drug (Anderson, 2006). These accounts are exemplary of how early careless tropical hygiene practices such as mass vaccination and use of chemical insecticides helped drive later drug and insecticide resistance.

The purpose of America’s occupation of the Philippines after the Spanish-American war was driven by economic desires to both replace Cuba as a sugar producer and to open new markets to the trade of American manufactured goods, creating a naïve and stable consumer base (Russell, 1899). “Much of development remained, at heart, a civilizing mission, disempowering local communities, demanding that the native or the underdeveloped person follow the single track toward a unique western modernity” (Anderson, 2006). Anderson’s work highlights that in the early 20th century colonial civilizing projects went through a rebranding process and became “development.” The “development” spoken of is of pure economic achievement, not necessarily indicative of social progress or betterment and is best nuanced by the late scholar Walter Rodney.

“As defined by the average bourgeoisie economist, development becomes simply a matter of the combination of given ‘factors of production’: namely, land, population, capital, technology, specialization, and large-scale production” (Rodney, 1972). In the conventional definition of development, Rodney stipulates that imperialism is a logical phase of capitalism. “Imperialism is itself a phase of capitalist development in which western European capitalist countries, the
U.S.A., and Japan established political, economic, military and cultural hegemony over other parts of the world [the Philippines] which were initially at a lower level and therefore could not resist domination” (Rodney, 1972). In addition to questioning early public health implications for development I would also like to contend with their framing of underdevelopment. Within public health discourse, nations in tropical worlds are often noted as ‘underdeveloped’ or ‘developing’, here Rodney provides further clarity and necessary critique lacking in dominate scientific and tropical medicine literature. “Underdevelopment makes sense only as a means of comparing levels of development,” with Europe and the West as unofficial standards. Rodney further emphasizes that an integral part of contemporary underdevelopment is the export of surplus, or the forced dependence on an export economy, which deprives societies of the benefits of their own natural resources and labor. “All of the countries named ‘underdeveloped’ in the world are exploited by others; and the underdevelopment with which the world is now preoccupied is a product of capitalist, imperialist and colonialist exploitation” (Rodney, 1972). To further nuance and contextualize Rodney’s claims in the Philippines, I would add that not only has overt U.S. and Spanish imperialism worked to under-develop the Philippines, but also that their importation of mosquito vectors and disease is a current means for underdevelopment.

**Food for Thought**

Dengue and mosquito-borne disease are complex multi-variate issues, however, in framing them using a historically situated and cross-disciplinary approach we are able to blend scientific research, history and social critique, in order to obtain a holistic understanding of the intertwined dynamics of mosquito, disease and society. To use contemporary ecological research to extrapolate upon colonial influence works to both break the boundaries of conventional academic disciplines and to reimagine the potential of future research. In essence, like disease, neither
science nor the humanities exist in bubbles and both can be used to help further and critique the other. It is worth noting that while scientific research may present as empirical and objective, the fact that it is designed and implemented by people raised in societies that continue to embrace imperialism, biological determinism, and white supremacy, make objectivity a false truth. Contemporary research, while not as overt as the aforementioned 20th century public health literature, requires special vigilance and historical grounding to tease out problematic subtext.

3.3 Limitations, Zika and Future Directions

Limitations to Argument

There are several limitations to both the arguments I have made and the research I have presented. While there is a consensus in contemporary published tropical medicine and ecological literature that dengue was not recognized in Southeast Asia or the Indian Ocean until the second half of the 19th century, there are conflicting historical accounts. For example, Smith 1956 provides a timeline of the global distribution of dengue and claims that there are records of dengue epidemics occurring on the coasts of India and Indonesia as early as 1779. However, Smith and other scholars concede that the accuracy of these sources is questionable, as reports of the symptoms of dengue vary widely and it is possible that these early mass outbreaks of disease were misdiagnosed sand-fly fever (Smith, 1956; Siler 1926).

While the introduction of dengue is suggested to have occurred around the late 19th century, there is no consensus in scholarly literature about the timeframe of the introduction of Aedes aegypti. While I suggest that Aedes aegypti predates dengue, as pre-established populations of mosquitoes may account for early rapid geographic distribution of dengue epidemics, it is possible that Ae. aegypti was co-introduced with dengue in the late 19th century. Conversely, it is
also possible both that *Aedes aegypti* and dengue were introduced by multiple avenues, as the Suez Canal, an artificial waterway in Egypt connecting the Mediterranean Sea and the Red Sea, opened in 1869. While population genetic study by Powell et al 2013 and Brown et al 2013 suggests a westward expansion of *Aedes aegypti* mosquitoes is foundational for many of my arguments, one explanation they offer is that Suez Canal may have accounted for North African ancestral populations of *Aedes aegypti* entering the Indian Ocean and thus expanding via trade route to S.E. Asia. However, this does not account for the similarities of Asian populations with those of the Americas. Powell and Brown’s study is limited, the genetic information used from the Pacific and S.E. Asia is sparse and data on the Indian Ocean populations is absent. While it is possible that there were multiple entry points of *Aedes aegypti* into S.E. Asia and the Indian Ocean, the lack of clarity and definitive contemporary research only furthers the need for a new population genetic research study.

Also, there exists a number of published research papers by the author Duane Gubler, which predates the population genetics study that works, unjustifiably off the notion that that *Ae. aegypti* is endemic to the tropics. The body of literature by this author is extensive and is cited at some point by the majority of contemporary literature on the topic. However, upon further investigation into Gubler’s work, I have only found one study that he uses to justify his claims: the 1956 paper by C.E. Smith that I have previously detailed. Further, it is worth mentioning that there is a potential conflict of interest regarding Duane Gubler, who as former director of the dengue division of the CDC and the National Centers of Infectious Disease and member of several WHO dengue committees, may be reluctant to investigate or support work that suggests that American or European colonization and tropical and military hygiene efforts have a
connection to the formation and distribution of *Aedes aegypti*, dengue and now drug and insecticide resistance.

**Zika**

The epidemiology of zika virus, the newest pathogen to be transmitted by *Ae. aegypti*, has key differences from the other arboviruses, dengue and yellow fever. Whereas dengue was the first known pathogen transmitted by *Ae. aegypti* to have fully adapted to people and not depend on an enzootic cycle for maintenance (i.e., it has no reservoir outside of people), recent studies indicate that zika virus differs in that it can be sexually transmitted by people (CDC Zika, 2016). Recent studies also suggest that the virus can be vertically transmitted from female mosquitoes to offspring, although this happens at low rates and is comparable to that of other filoviruses such as dengue, yellow fever and chikungunya that can be passed to eggs (Thangamani et al 2016).

The arboviruses transmitted by *Ae. aegypti*, cannot be sexually transmitted and are dependent upon a mosquito-human-mosquito or animal-mosquito-human life cycle.

Zika was first recognized in 1947, but was discarded from further study as its symptoms were often non-lethal and relatively mild. Today it is associated with Guillain-Barre´ syndrome, a debilitating neurological disorder, as well as an increase of microcephaly in infants (Messina et al 2016). Zika virus is particularly a concern for pregnant women as it is thought to increase the incidence of microcephaly, infants born with small heads and decreased brain function.

The fact that zika virus can be spread human-to-human, without the involvement of mosquitoes, further suggests that mosquito-borne pathogens are adapting and evolving. While research into zika virus is recent, some studies suggest that previous exposure or acquired immunity to other arboviruses in the same family, in particular dengue, may increase susceptibility to zika and to more serious forms of zika fever (Paul et al 2016). The emergence and new characteristics of
 Zika virus further nuance the idea of an evolutionary arms race and further justifies the need for a historically situated and integrative public health approach that is proactive in identifying the creation of the conditions for disease and adaptation.

**Consequences and Future Directions**

If we continue to ignore history and the importance of land use and if we fail to frame epidemics of mosquito-borne disease as man-made creations that have unintended consequences as opposed to random unfortunate events, we risk endlessly repeating the conditions for disease and adaptation. The cycle of reactive public health prescriptions and interventions as opposed to nuanced proactive approaches is leading to a mosquito or pathogen adaptation that does not have an immediate fix. Continuing to rely on technological and biomedical advances to combat changing mosquitoes and pathogens in an evolutionary arms race is dangerous and irresponsible.

To help clarify my multiple hypothesis concerning the original spread of *Ae. aegypti* and dengue, I argue that there needs to be new and more cross-disciplinary research and collaboration in this field of research. I propose that a new population genetic study be conducted to help further detail and clarify the varying hypotheses about the global, likely trans-Pacific spread of *Ae. aegypti* and dengue. In addition, I argue that there is a need for more research into the interactions between ecology, land use and the dynamics of *Ae. aegypti* and dengue in the Philippines, as studies from similar island nations like Martinique, are showing alarming trends.
Works Cited

Print and Archival Sources


Scientific Literature


**Public Health Resources**


