CHAPTER 14

Direct and Indirect Social Drivers and Impacts of Vector-Borne Diseases

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14.1 Introduction

Vector-borne diseases are often thought of by the highly developed nations of the Northern Hemisphere as a 'problem' of the tropics, conjuring images of mosquito-borne diseases, such as malaria, caught on vacation or relegated to the poorest of the poor. In this chapter, we seek to move the conversation beyond the 'neglected tropical disease (NTD)—poverty trap' framing of the interactions between vector-borne disease (VBD) and social contexts. First, we briefly review the poverty trap concept with respect to VBDs and their management to assess the management narratives they may fit. We then present a series of vignettes to illustrate different facets of the broad range of social drivers which interact with VBDs. We explore the repeated emergence and establishment of mosquito-borne arboviruses (e.g. dengue, chikungunya, and Zika) in the urban social-ecological context, and the multiscale challenges to managing these diseases in Latin America and the Caribbean. Next, we explore the lessons learned in developing community-based programs for control of VBDs in Haiti that are centered on trust and community involvement. We then explore the drivers and impact of recent ruminant arbovirus emergence events in Europe, and the extent to which they mirror human VBD events. These vignettes highlight the importance of reframing VBD narratives about emergence and spread, in terms of their context and system drivers, rather than simply lumping them as 'problems of poverty', in order to identify best practices in moving research from the field onto the desks of decision makers.

14.1.1 The VBD-Poverty Trap Paradigm

The connection of VBDs with the global poor is in many ways an environmental link, with a coincidence of tropical climates and large, exposed populations. In children under five years of age, diseases such as malaria and persistent parasitic infections result in a cycle of fever and stunting, leading to delayed development, low cognitive scoring, and a consistently immunologically compromised workforce. This is thought to contribute to a poverty trap—a cycle of the poor staying poor and sick (Bonds et al. 2010). This logic underpins many global health programs and strategies, and ties development, health goals, and funding together. While this remains a persistent component of many VBD systems, the simplification runs into the hazard of colonial overtones disguised as environmental determinism and overlooks the

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Box 14.1 Lessons learned about social drivers and feedbacks of vector-borne diseases

- Vector-borne diseases (VBDs) are often considered diseases of poverty, but this reductive approach does not explore the myriad of social and economic factors that influence transmission systems.
- In addition to economic resources, social and political factors have been shown to have profound influence on the timing and severity of outbreaks.
- The occurrence of disasters, both natural and unnatural, can damage public health infrastructure, deplete resources, and precipitate rapid shifts in housing density and social structures, increasing local VBD transmission.
- Local political and economic histories can influence current social drivers of disease, where public perception and trust determine the success of intervention efforts.
- Social, economic, and cultural influences on zoonotic VBD transmission and management can mirror those observed in human VBD transmission systems.

many nuanced ways in which that and additional historical and social contexts shape implementation of intervention.

Many VBD risk factors at the household level result indirectly from the macro-drivers of infectious diseases across the globe: poverty and inequality. This confronts us with the rather large goal of ending poverty to control VBDs. In some instances, forming policies targeted on poverty has been a successful approach to managing VBDs, illustrating the poverty-trap paradigm. For example, the decline in malaria in the Ohio River Valley during the early 20th century was due in large part to reductions in poverty and social inequalities (Farmer 1996). Reduced poverty led to improved housing conditions and access to mosquito control strategies—which reduced transmission and morbidity. While this and other examples underscore a link between broadscale reductions, resigning VBDs to problems arising from poverty may inadvertently lead public health officials to overlook key mechanisms important to controlling diseases on local scales. Conversely, if aid packages aimed at poverty seek to mitigate VBDs, these may miss countries higher on the development spectrum.

Many of the most intensely managed VBDs are considered Neglected Tropical Diseases (NTDs). Neglected Tropical Diseases are defined as a 'diverse group of communicable diseases' (World Health Organization 2012) found in tropical and subtropical countries, and are described as primarily associated with conditions of poverty. The WHO updated the list of Neglected Tropical Diseases at the 10th meeting of the Strategic and Technical Advisory Group for Neglected Tropical Diseases, in 2017 (see Table 1). As Molyneux (Molyneux 2012) pointed out after the 2012 London Declaration on Neglected Tropical Diseases (http://www.unitingtocombatntds.org), NTDs had achieved 'brand identity', necessary to attract attention in the Millennium Development Goals (MDGs) independently of HIV and malaria initiatives. Of this updated WHO list of NTDs in 2017, eight are VBDs—six involving insects (mosquitos and flies), one snails, and one, copepods. Slightly more complicated lists of diseases are the Neglected Infections of Poverty (NIPs) and the CDC's Neglected Parasitic Infections of Poverty (NPIPs), of which the CDC has created a list of five priority infectious diseases in the USA (Table 2). Of these, only one, Chagas, is a VBD. In Hotez's 2011 piece, originally describing NIPs in the USA, he makes the policy recommendations to examine VBDs, such as Chagas and dengue, along the Mexico border regions of the USA, and in post-Katrina Louisiana (Hotez 2011). The emphasis on dengue has faded from the CDC's NPIP list and more recent descriptions (Hotez 2014), but recent emergence of both chikungunya and Zika in similar geographic areas, and the associated post-hurricane uptick in concern (e.g. Harvey, Irma, and Maria of 2017), suggest perhaps a revisiting of this connection (Diaz & Stewart-Ibarra, 2018). The poverty-trap paradigm for VBDs can certainly enhance our understanding of these diseases in certain contexts but is not a 'one size fits all' solution. Thus, we aim to present some of the many complex social and cultural interactions that influence VBDs, which may be key components in developing effective public health interventions.

14.2 Social Factors in the Transmission of Vector-Borne Diseases: Reflections from Ecuador and Latin America

Across the Americas, *Aedes aegypti* and *Aedes albopictus* transmitted diseases (dengue fever, chikungunya, and Zika fever) are extending in range and prevalence due to social and environmental conditions. Dengue fever is caused by the dengue viruses (DENV1–4) that can cause illness in people ranging from mild febrile illness to severe hemorrhagic fever and death (WHO 2009). The recent emergence and epidemics of chikungunya (CHIKV) and Zika viruses (ZIKV) in the same populations demonstrate that new viruses can quickly enter the agent-host-environment trio where DENV has flourished for so many decades (Paixão et al. 2018).

Many factors are responsible for the emergence and expansion of dengue fever, with social and demographic changes playing an important role (Gubler 1997). The emergence of DENV infections worldwide in the eighteenth and nineteenth centuries was driven by the expansion of rapid capitalist global commerce, during which humans and mosquitoes were transported long distances by improved nautical technologies, moving along colonial era trade routes (Gubler 1997). The resurgence of the disease in the late twentieth century is correlated with urban population growth, persistent urban inequalities—wherein a mosaic of rich and poor neighborhoods led to, and result from, schisms in access to basic services, the rise of slums, etc.—and global travel, among other factors (Gubler & Meltzer, 1999).

Over the last forty years, social drivers primarily associated with urban areas, such as high population density, poor sanitation, deterioration of public health systems, and lack of effective vector control programs, have contributed to the rise of *Ae. aegypti*-transmitted illnesses in the Americas. *Ae. aegypti* is exceptionally adapted to the urban human environment. Female mosquitoes blood-feed on people in the home during the day, and water-filled containers around the home and patio are the ideal habitat for mosquito larvae. From 1960 to 1980, mid-sized cities in Latin America experienced rapid unplanned growth, resulting in social inequalities to urban infrastructure (e.g. piped water, garbage collection) and the expansion of slum settlements, often related to deteriorating and/or changing economic and political contexts (Harpham & Molyneux 2001; Kendall et al. 1991; Satterthwaite 2003). Devastating dengue fever outbreaks followed shortly after, and since then the Latin America and Caribbean (LAC) region has reported the highest rise in dengue transmission worldwide (Stanaway et al. 2016). From 2000 to 2006, 68 percent of all cases worldwide were reported from LAC, with regional outbreaks occurring every three to five years (Cafferata et al. 2013).

Ecuador is classified as a highly developed country; the United Nations Development Program (UNDP), using the Human Development Index (HDI), places Ecuador in the 'high human development' category (United Nations Development Program 2018). In Ecuador, *Ae. aegypti*-transmitted illnesses have replaced malaria (transmitted by *Anopheles* mosquitoes) as the most prevalent mosquito-borne diseases ('Dirección Nacional de Vigilancia Epidemiológica', n.d.). Over a five-year period (2012 to 2016), 103,005 cases of DENV were reported in the country, compared to 1,861 cases of malaria. A highly effective malaria control program (Krisher et al. 2016), aimed at controlling *Anopheles* mosquitoes, coupled with growing urban areas, resulted in a decline in malaria transmission and the proliferation of *Ae. aegypti*. This program declared elimination status for malaria in southern Ecuador in 2012, and substantially scaled back surveillance and intervention for malaria, subsequently.

In the southern coast of Ecuador lies El Oro Province, bordered by Peru in the south, the Pacific Ocean in the west, and the Andean foothills in the east. DENV is hyper-endemic in El Oro, with an annual peak in transmission during the hot, rainy season from February to May, when mosquito populations are at their highest (Stewart-Ibarra et al. 2013; Stewart-Ibarra & Lowe 2013). The first outbreaks of CHIKV and ZIKV occurred in 2014–2015 and 2016–2017, respectively. Currently, there are no vaccines for CHIKV or ZIKV (Cohen 2016; Smalley et al. 2016). The DENV vaccine is not available in Ecuador, and is currently the subject of intense international scrutiny following recognition that the vaccine increases risk of severe DENV infections in sero-negative individuals (particularly children)

(Aguiar et al. 2016; Halstead 2017; Larson et al. 2019). Given the lack of vaccines or specific therapeutics, vector control remains the principal means for preventing and controlling *Aedes*-transmitted illnesses and outbreaks. In Ecuador, vector control includes regular household visits by Ministry of Health (MoH) inspectors to eliminate or treat containers with standing water with organophosphate larvicide, and focal control around homes with arbovirus infections using ultra low volume (ULV) fogging and indoor residual spraying (IRS). Over the last few years, the vector control system of the MoH in Ecuador has, from a management and organizational perspective, shifted from a centralized vector control program towards a decentralized program, spread more evenly across the health districts, allowing for greater decision-making power at the local-level. In addition to decentralization, the integrated strategy supported by the Pan American Health Organization (PAHO) is 'expected to produce a qualitative leap forward in prevention and control through stronger partnerships among the State, its various ministries, and governing bodies, private companies; and the range of community and civil groups' (Luis et al. 2007; Morrison et al. 2008a). In comparison to past approaches, this policy emphasizes significant intersectoral coordination and community involvement. However, implementation has been slow and challenging because of the need to reallocate costs to previously unfunded social mobilization initiatives, as well as the need to link knowledge of local social factors that influence disease transmission with operational activities (Leon 2017).

14.2.1 Social Risk in Coastal Ecuador

Studies in Machala, Ecuador, have characterized the complex social and environmental factors driving arbovirus transmission using a social-ecological (SES) systems approach. These studies found that *Ae. aegypti* population dynamics are influenced by an unexpected number of complex social-ecological risk factors at the local level, including risk perceptions, access to municipal services, water storage behaviors, and poor housing conditions (Stewart-Ibarra et al. 2014). Community focus groups conducted in the city identified these local risk factors, which were grouped into bio-physical, political-institutional, and community-household factors (Stewart Ibarra et al. 2014). In terms of the way that DENV risk was conceptualized by community members, urban development issues were among the most significant. Access to municipal public services and utilities (e.g. garbage collection, sewerage, piped water) were also a major concern, especially in the peripheral areas of the city, where infrastructure inequalities are at their highest. The findings in coastal Ecuador are consistent with our understanding of the behaviors of *Ae. aegypti*, and the ways in which this mosquito is inextricably linked to social conditions. The vector predominates in urban settings where crowded conditions and lack of infrastructure contribute to the transmission of DENV (Gubler 1998; Morrison et al. 2008b). Year round in Machala, household water storage provides the ideal habitat for mosquitoes. It was found that storage of tap water in containers, such as fifty-five-gallon drums, increased the risk of *Ae. aegypti* around the home year round, whereas abandoned containers filled with rainwater increased *Ae. aegypti* abundance during the rainy season. Households with an unreliable piped water supply (frequent water supply interruptions) are more likely to store water in containers, which become potential mosquito larval habitat (Stewart-Ibarra et al. 2013).

Household-level social factors are not the only critical drivers of vectored disease transmission. In fact, political-institutional perceptions were shown to be important social drivers, because attitudes and opinions of citizens determine their willingness to adopt disease control actions and thus have the potential to influence governmental decisions and shifts in policy and management. Dengue epidemics can overwhelm hospitals and clinics, leading to overworked health care providers and sub-standard care for patients. Mesoscale socioeconomic patterns also affect attitudes and perceptions in public health, with communities living in low-income neighborhoods in the periphery of Machala feeling that they were neglected by the government (Stewart Ibarra et al. 2014). Equipped with limited resources to conduct surveillance, as is the case for many dengue endemic countries, local MoH officials are often scrambling to offer a response that has a high impact on community perceptions (Gubler 1998). This has led to the reliance on ultra-low volume spraying (ULV) during epidemics, since it is a highly visible action that demonstrates governments are actively doing something to control the spread of disease (Gubler 1989). Both ULV spraying and larvicide application are highly visible actions, as illustrated in Machala, Ecuador (Figs 14.1, 14.2). Although ULV spraying has the potential to cut transmission during outbreaks, it is an expensive strategy that has limited efficacy in areas with high levels of insecticide resistance (Gubler 1989; Reiter & Newton 1992). In Machala, we

Figure 14.1 MoH staff fumigating a home while the owner watches on (urban periphery, Machala).

Source: Dany Krom https://www.danykrom.com/STORIES/Vector-born-Diseases/

Figure 14.2 MoH staff visiting a home to apply larvicide, while the woman of the household waits.

Source: Dany Krom https://www.danykrom.com/STORIES/Vector-born-Diseases/

found that households reporting fumigating had lower risk of DENV infections (Kenneson et al. 2017), suggesting it is currently a viable strategy, if implemented properly.

The social impact of these events is that communities will demand spraying that may not address the causes of disease risk, or simply may not reduce infections. We recently found evidence of high levels of insecticide resistance (IR) in *Ae. aegypti* among four cities in southern Ecuador, including Machala, indicating that this is an emerging problem (Ryan et al. 2019). The study found that rates of IR were highest in Machala, which has the highest historic dengue burdens among the four cities studied. More nuanced examinations of socioeconomic and subcity level geographic stratification are needed before we can fully assess the links between demand, implementation of ULV spraying, and IR. If a coincidence of ULV spraying and high levels of IR arise, confidence in vector control may begin to erode, and political will, rather than a reexamination of strategy and efficacy, may dictate the next step.

Whereas environmental conditions are drivers for *Ae. aegypti* population dynamics and dengue incidence at large scales across regional areas, social factors can account for differences at the subregional and within-city level. For instance, a study conducted across comparable sites in Arizona, USA, and Sonora, MX, found that *Ae. aegypti* presence was positively associated with highly vegetated areas, and reduced with access to piped water (Hayden et al. 2010). This result appears to contradict our findings in Machala; however, the quality of piped water—in Machala, intermittent service was associated with higher risk—is likely the driver of these differences. In the study comparing Arizona and Sonora, the social factors across the cities varied greatly, with all locations on the U.S. side of the border having access to public health infrastructure (piped water, sewage, sanitation), but many households without access to the same infrastructural amenities on the Mexican side of the border. In Ecuador, the effects of rainfall on dengue risk varied by neighborhood within a city, depending on whether the main larval habitats were water storage containers with tap water (in the urban periphery) or abandoned containers with rain water in the patio (Stewart Ibarra et al. 2014; Stewart-Ibarra et al. 2014, 2013). Studies on malaria prevention have also found similar patterns of VBD intervention access inequalities. Prior to the mass distribution of free insecticide-treated mosquito nets in El Oro, Ecuador, that achieved great equity in coverage, access to bed nets was largely dependent upon wealth (Nuwaha 2002; Rashed et al. 2000; Steketee & Eisele 2009; Wiseman et al. 2006).

Studies in periurban communities in Machala, Ecuador have shown that the economic burden of mosquito prevention is significant for low-income households. Multiple studies conducted in Machala between 2013–2015 have shown that low-income households employ many mosquito control interventions to reduce the burden of *Ae. aegypti* transmitted illness, though the effectiveness of these household-level interventions needs to be evaluated. Members of periurban communities reported economic barriers to DENV prevention in qualitative studies (Stewart Ibarra et al. 2014). This was validated through household surveys, which found that the economic burden of mosquito control was significant in low income households (Heydari et al. 2017). Households spend upwards of 10 percent of discretionary household income, or income that is left for spending after paying for household necessities (e.g. food, housing, gas and water) to prevent mosquito-borne diseases (Heydari et al. 2017). The findings show a healthy and robust market for commercial mosquito products in small neighborhood stores and large, centrally-located supermarkets. Novel interventions that are low cost and effective at reducing the population of *Ae. aegypti* are urgently needed. Innovative control strategies are promising, such as lethal ovitraps, insect growth regulators, and attractive toxic sugar baits (Andrade et al. 2016; Johnson et al. 2017; Paz-soldan et al. 2016; Scott-fiorenzano et al. 2017). However, the success of these strategies will rest on economic latitude and social acceptance and require ongoing trials in the region to determine viability.

The economic situation and levels of poverty play important roles in disease transmission across multiple levels (e.g. macroeconomic level and microeconomic level). At the household level, economic barriers/limitations were the most commonly mentioned barrier to *Ae. aegypti* control across several studies in Machala, Ecuador (Heydari et al. 2017;

Stewart Ibarra et al. 2014). Home ownership and job stability, proxies of poverty, were associated with expenditures on vector control. There can exist striking differences in human housing factors including screened windows and doors, irrigation, and vegetation—all factors that play a key role in the presence or absence of *Ae. aegypti* in and around households (Chang et al. 1997; Kay & Nam 2005; Nagao et al. 2003). To illustrate this juxtaposition of housing quality, a five-star hotel with air-conditioning, screens on all windows, and a garden that is well maintained is located less than five blocks away from several neighborhoods where air-conditioning units and screens are rare, and abandoned lots (Kenneson et al. 2017) are found on every street. Ironically, many of the hotel workers live in the surrounding neighborhoods, meaning that viral transmission is likely also occurring, albeit at less frequency due to reduced biting rates, within wealthier social groups. Family income to purchase *Ae. aegypti* control strategies may lessen the risk of falling ill with arboviruses, although it is not hard to imagine a situation in which a hotel guest sun-bathing poolside is bitten by an *Ae. aegypti* mosquito that has emerged from the cistern of a neighboring household. Improving equity across local sites—that is, bringing whole neighborhoods and cities into an improved standard of living, with improved access to public health and vector control interventions—will be needed when considering economic and public health improvements to fully mitigate VBD transmission, given that the flight radius of the *Ae. aegypti* is around 200m.

14.2.2 Increasing Vulnerability Following a Natural Disaster

There is a well-established connection between human activity and *Aedes* presence (Shragai et al. 2017), but not all *Aedes* risk is caused by humans. Natural disasters, such as earthquakes and hurricanes, damage public health infrastructure and housing, consolidate economic inequalities, and increase the incidence of disease. On 16 April 2016 a 7.8 magnitude earthquake devastated the north-central coastal region of Ecuador just as the ZIKV epidemic was emerging. The earthquake claimed the lives of 663 people, injured over 6,000, displaced nearly 30,000, and caused severe damage to households and public health infrastructure, leaving families without homes and vulnerable to mosquito-borne infections (Secretaria de Gestion de Risegos 2016). Out of necessity, families stored water in fifty-five-gallon drums, large water jugs, elevated tanks, and other containers that make ideal *Aedes* larval habitat, since water systems were damaged. In areas that already faced problems with inadequate water supply, the earthquake further exacerbated the problem (Ryan et al. 2016). In the earthquake-affected province of Manabi, Ecuador, there was a spike in suspected and confirmed ZIKV cases among the general population and among pregnant women in the aftermath. After the earthquake, the cumulative number of ZIKV cases in Ecuador increased from 103 to 1275 in eleven weeks, with 85 percent of all ZIKV cases in 2016 reported from Manabi Province, near the epicenter (*Zika Gazette SE 38–2017* 2017). This finding is consistent with studies in other disaster zones; for example, with malaria prevalence increasing following an earthquake in Southeast Asia (Feng et al. 2016).

The destruction of property and public health infrastructure is likely to increase *Ae. aegpyti* larval habitat in itself, and the displacement of families and overcrowding is likely to further increase mosquito-borne disease transmission due to an increase in exposure to mosquito bites and infected individuals (Salazar et al. 2016). In fact, most of the increased risk of VBDs following a natural disaster can be attributed to conditions related to population displacement (Watson et al. 2007). Many of the homes that were still standing in Manabi Province were deemed by government officials unsafe to occupy. Families without stable housing migrated into small living quarters, sometimes donated by non-governmental organizations (NGOs), other times a makeshift tent consisting of only simple tarps, fastened into walls. During our last visit to the area, more than one year after the earthquake, some of these ‘temporary’ living spaces were still in use. Lastly, we observed that during the subsequent efforts to rebuild homes post-disaster, the number of persons living in a household had increased. This rapid shift in housing density could further compound disease transmission risk in the area. Studies in southern Ecuador prior to the earthquake found that higher urban population density, indicated by the number of households per property, was a positive predictor for the presence of *Ae. aegypti* (Stewart-Ibarra et al. 2013).

As a point of comparison, it is worth highlighting the impacts of tropical storms in the Caribbean on arbovirus transmission. In the island country of Dominica, DENV is an ongoing arboviral disease concern, and recorded cases since 1993 show that in epidemic years, there are seasonal signals (Stewart Ibarra et al. 2017); and cases have been reported every year since 2006, according to epidemiological records. In 2014, CHIKV swept through the Caribbean, including Dominica, and in 2016, 1,263 cases of ZIKV were reported during the initial outbreak (Ryan et al. 2017a). Household water storage increased after Tropical Storm Erika in 2015, as reported by local health officials in interviews (Stewart Ibarra et al. 2017; Stewart-Ibarra et al. 2019). The storm damaged the piped water systems and rivers were contaminated, resulting in a scarcity of potable water. As a result, homes began storing water in drums, and this practice continues two years later even though most homes (>90 percent) now had access to reliable piped water, as Dominica is a country with an abundance of freshwater. Dominica and other Caribbean territories were devastated again during the 2017 Atlantic hurricane season, one of the most active seasons on record. It is suspected that the risk of arbovirus transmission increased in the region due to significant damage to housing and other infrastructure, and relocated populations. As observed in Dominica, these amplified social risk factors may remain present years after the disaster.

We hypothesize that psychological distress resulting from natural disasters can also increase the risk of arbovirus transmission by impairing the immune response (Cohen and Williamson 1991; Glaser et al. 1987). Posttraumatic stress disorder (PTSD), suicidal ideation, depression, and anxiety are commonly reported in natural disaster survivors (Chen et al. 2001; Stewart-Ibarra et al. 2017; Zhang et al. 2014). In areas with scarce health system resources, access to mental health care is often limited and socially stigmatized (Borowsky et al. 2000; Harding et al. 1980). Lack of access to mental health care is exacerbated in a post-disaster setting due to competing health priorities. In Ecuador, three months after the earthquake, we found that women, adults, and displaced people who reported more psychological distress symptoms were more likely to report arbovirus symptoms in low-income communities than in higher income communities (Stewart-Ibarra et al. 2017). These findings suggest that there are complex multilevel interactions that affect the mosquito vector and arbovirus transmission following a natural disaster including individual risk factors (e.g. immune response, stress, age, gender) and community-level risk factors (e.g. housing damages, water and healthcare access).

14.2.3 Regional Politics: Unnatural Disasters

It is not easy to pinpoint the moment that Venezuela's economic collapse started, but a combination of falling oil prices and political struggle have meant that the richest economy in the Latin American region has plummeted to a crisis state in under a decade. This has had severe impacts on health, the scope of which are now coming to light—a review of vaccine-preventable disease resurgence in Venezuela pointed out that with an economy suffering 45,000 percent hyperinflation, the health system went into free fall (Paniz-Mondolfi et al. 2019). Measles cases in and from Venezuela represented 68 percent of cases in Latin America in 2018, and Diptheria, previously eradicated, has re-emerged (Paniz-Mondolfi et al. 2019). The implications of this health system collapse for VBDs is two-fold; within Venezuela, the capacity to conduct surveillance, vector control, and treatment has evaporated, and beyond the borders, a massive exodus of the population, migrating through and to surrounding countries, has led to new routes of transmission, and potential spread. In Venezuela, malaria cases rose 359 percent between 2000 and 2015, while neighboring countries in the region were driving toward elimination, and between 2016 and 2017, an increase of 71 percent in malaria cases in Venezuela led to noticeable upticks in imported cases in neighboring countries (Grillet et al. 2019). In 2017, Venezuela contributed 53 percent of the malaria cases in the Americas (World Health Organization 2018).

The current social and political crisis in Venezuela is now influencing vector-borne disease transmission dynamics across the Americas (Grillet et al. 2019). Approximately 3 million people have fled Venezuela, many to other countries in South America. In 2018, the first new locally acquired cases of malaria were reported in El Oro, Ecuador, and Tumbes Region, Peru, following the elimination of malaria in 2011/2012 (Jaramillo-Ochoa et al. 2019). These cases appeared after a series of imported malaria cases were detected in Venezuelan migrants in El Oro and Tumbes. Known malaria mosquito vectors are abundant and present in the region (Ryan et al. 2017b), meaning elimination status is tenuous if regional elimination goals are not maintained. Paralleling malaria importation, prior phylogenetic analyses of DENV from Machala found that they were closely related to DENV from Venezuela (Stewart-Ibarra et al. 2018). This highlights the key role that regional politics and migration can play in disease transmission, and the need for Ecuador and other countries in the region to strengthen integrated vector-borne disease surveillance and control in the border regions, and along migration routes, where human movement poses a major challenge.

14.3 Building Trust in Haiti: Reflections from the *Polisye Kont Moustik* (PKM) Project

Haiti was officially founded in 1804, the first free black republic, after more than a decade of bloody revolt spearheaded by bands of African plantation slaves (Dubois 2012). Founded in 1697, *St. Dominque* was the most profitable slave settlement in the Caribbean, supported by a brutal system of dehumanizing mono-crop agriculture, organized around the supply and demand laws of Europe's burgeoning sugar industry. Newly imported West Africans were segregated based on language and ethnic identity, and made to work until they died from exhaustion, malnutrition and disease, often in combination. A large bronze statue of the *Batay V`ètyè* (Battle of Vertières), the last independence battle, led by the legendary Jean Jacques Dessalines, stands in a small park along the main highway connecting Cap-Haitien (Haiti's second largest city) with the capital, Port-au-Prince. As with other islands in the West Indies, tropical diseases, especially yellow fever and malaria, were a key element of these colonial battles. McNeil, in *Mosquito Empires: Ecology and War in the Greater Caribbean, 1620–1914* (McNeill 2010), argues that while malaria was 'the white man's grave' in West Africa, yellow fever played a more formidable role in hastening in the first Black Republic, acting as 'shields for local populations'. The French forces sent by Napoleon during the *Batay Vètyè* were never able to successfully penetrate the mountainous Haitian landscape. They were decimated by yellow fever, due to a lack of acquired immunity, while suffering from a war-ravaged economy and diminishing supplies (Peterson 1995).

History has a long shadow in places like Haiti. While 'free', the country has seen continued foreign intervention, including an often-forgotten occupation by the United States (1915–34), and an elite 'mulatto' class more interested in maintaining economic and political dominance than in transformative social and democratic change. While the island of Hispaniola is shared with the Dominican Republic (DR), aerial images show a forested DR and a de-forested Haiti, a metaphor for how different histories, cultures and state-citizen relations have produced uneven capabilities (Sheller & León 2016; Stoyan et al. 2016). The 'poorest country in the Western Hemisphere', Haiti has some of the worst health indicators globally; the health delivery landscape is fragmented, dominated by professional and faith-based NGOs and heavily reliant on international aid.

Why is all of this important? How does history and politics play into the current social drivers of VBDs? One of the legacies of this political and economic history is that in modern Haiti, there is little faith and trust in government institutions and foreign aid interventions. For the last two years, *Polisye Kont Moustik* ('Mosquito Police' or PKM), a new community-based vector control program, has been exploring how to build community trust and social relationships as an essential part of an 'effective' public health program, in communes around the old battlefields of *Batay Vètyè* in northern Haiti (Bardosh et al. 2017).

The literature on trust, as a component of vector control, is relatively thin—alluded to but seldom discussed. A study in Peru, for example, pointed to real or imagined burglaries instigated by outreach staff as drivers for community resistance to vector control outreach (Charette et al. 2017). In Ecuador, a community-based randomized *Aedes* control trial intervention, using elementary school-based education and community-wide cleanup and education, found that the strength of local community-based solidarity and political action played a major role in effectiveness (Mitchell-Foster et al. 2015). These, and other studies, conclude that vector control depends on much more than 'knowledge, attitudes and practices' (Launiala 2009), but also on very hard-to-quantify cultures of local municipal governance, community participation and social cohesion. This influences, for example, the willingness of local people to let vector control staff enter their houses, and the level of importance given to interpersonal communication during these visits. Persuasion is a key aspect of social negotiations between vector control staff, families, mosquitoes, and water containers. Encouraging participation and engaging in knowledge dissemination will require different strategies in different contexts. These negotiations and implementations are also political; for example, Nading's ethnography of dengue control in Nicaragua (Nading 2014) showed how vector control outreach focused on 'eliminating breeding sites' can exasperate social divisions between health workers and garbage scavengers—those whose livelihood depends on collecting, storing and selling recycling material.

Our efforts in Haiti, originally funded by Gates Foundation and now USAID, have focused on developing an effective larval source management (LSM) program that engages municipal governments, local community groups and families. Originally, our efforts were focused on integrating LSM with the Haitian Lymphatic Filariasis (LF) Elimination Program. In the face of adversity, the LF program has been hugely successful in Haiti, and is focused on annual rounds of community-wide mass drug administration (MDA) with deworming drugs (Lemoine et al. 2016). But some persistent parasite foci stubbornly remain, mostly in urban areas, raising the prospect that it may be necessary to target the mosquito *Culex quinquefasciatus* which breeds in polluted and stagnant water, especially in poorly built and maintained cement canals (Burkot et al. 2006). With this mosquito-borne disease now targeted for global elimination by 2020, it is curious that vector control has remained such a peripheral part of the Global LF Elimination Program.

Our original pilot project focused on the small town of Plaine-du-Nord, with roughly 2,500 households and 10,000 people. An important voodoo pilgrimage site surrounded by fertile agricultural land, the town was once the 'bread-basket' of Haiti. During the first nationwide lymphatic filariasis (LF) prevalence survey conducted in the early 2000s, Plaine-du-Nord had a staggering 45 percent filarial antigenemia prevalence, the highest prevalence in Haiti and among the highest globally (de Rochars et al. 2004). But Plaine-du-Nord is also endemic for other VBDs. Malaria has long been endemic in the floodplain. While yellow fever has long vanished, new pathogens like chikungunya and Zika are now widespread, and have integrated themselves into the local disease lexicon. Fig. 14.3 shows an open sewer flowing in the middle of an unpaved road, tangles of electrical wires (that often do not work) and an advertisement from a local 'doctor' for physio-therapy to treat chikungunya, now considered a chronic disease, alongside rheumatism and hypertension, by many in northern Haiti (note that he also provides veterinary care).

When the project was getting off the ground, our first training in the office of the Ministry of Public Health and Population (MSPP) was infested with *Aedes* mosquitoes. Attributed to the chikungunya epidemic in 2014 that swept through the Caribbean, a team member suffered from epileptic-like seizures, and the MSPP medical director suffered chronic joint pain and headaches. In our ethnographic fieldwork, we found that chikungunya was by far the most feared and talked about mosquito-borne disease. Known locally as 'paralysis', nearly 50 percent of people in our household surveys ($n = 293$) reported that they had been infected with the virus in 2014, often sick for weeks.

Building trust and social relationships in Plaine-du-Nord, in the early stages of the PKM project, involved a few interesting and distinct steps. First, the strong community experience with chikungunya meant that, despite our funders being inter-

Figure 14.3 An advertisement from a local 'doctor' for physio-therapy to treat chikungunya, northern Haiti.
Source: Kevin Bardosh

ested in LF, malaria, and then Zika, we found it necessary to emphasize chikungunya in our risk communication and community engagement, to connect to experiential context. This siloed approach to specific intervention targets is a common and unfortunate aspect of vertical disease-specific global health initiatives: for instance, the malaria program can only distribute bednets and target *Anopheles* breeding sites, the LF program can only clean canals, and the Zika program can only do household visits. In order to speak to the priorities and risk perceptions of community members, our focus became more of an integrated vector management approach—an effort to include VBD control strategies with multiple targets, and bundled approaches.

With Haiti's history of colonialism and sense of exploitation from NGOs, it was interesting to see how community members interpreted and responded to foreign American staff visits. In some ways, these were negative. Early on, some community members became angry when their photograph was taken during a food distribution as part of a community-wide larval habitat cleanup campaign. They were concerned that the picture would be shown internationally, and that the American project staff would use it to 'make money'. This was a common theme: the idea that NGOs *used* community members for self-gain, and only did 'little work'. Some rumors began to circulate after this incidence. To address them, we initiated a series of community dialogues, which included inviting religious groups, municipal leaders, health staff, school teachers and informal leaders. From this, the initial 'rumor-spreaders' (a group of politically savvy local artists) became our most vocal and involved advocates. Interestingly, over time, community members asked for more 'foreign oversight' and involvement, citing suspicions of Haitian elites managing health services.

Engagement with the community also meant negotiating a 'partnership' with various local political leaders, each which had their own political agenda. During the early phase of the project, garbage was used as a political weapon, repeatedly dumped on the streets of towns to damage the reputation of the town mayors and to 'sabotage' our first cleanup campaign. Our effort at mosquito control had political value for these leaders. In this way, they collaborated with us. But they did it strategically, often more focused on showing up to large events than contributing anything too substantial (such as staff or funding).

A major area of conflict with local leaders involved our efforts to hire staff. The PKM approach is based on hiring local staff, who conduct daily household visits where they engage in cleanup activities, education, community mobilization and apply Bti (*Bacillus thuringiensis israelensis*) for vector control. It is important that these staff are from the areas that they work in; the project had to consult local leaders for the recruitment process. At first, most recommended workers were not interested or able to work the long hours or did not have the proper inter-personal skills. They had been selected to return political favors during the recent election campaign. It took time to replace these people, without damaging our own relationship with the municipal authorities. Eventually, we developed a recruitment system that was 'democratic'. It included each leader of a *quartier* nominating two to three people, who would undergo training, and then take a practical and written test. Recruitment was based on these test grades, which were posted publicly around the town.

As we scaled-up the project and expanded to neighboring communes, one of our key leadership staff tampered with the test results to promote their friends. People noticed this, and it was the talk of the town, threatening to derail an otherwise carefully planned out process. A quick town-hall meeting was called, with witnesses, accusations, and counter-accusations, leading to dismissal of the staff member. Such occurrences happened continuously over two years, in multiple variations and in many different settings. While we used flyers posters, banners, loudspeakers, radio messages, drama, comedy, murals and competitions to engage community members in mosquito control in northern Haiti, these lessons tell us something different—something relatively simple but hard to put into practice, that has been increasingly discussed in the post-Ebola literature reflecting on the 2014–2016 West African epidemic (Wilkinson et al. 2017). To be effective, these activities need to be implemented with *trust*, something that demands constant attention, constant tinkering and adapting, alongside local political spheres and the management of everyday life.

14.4 Livestock VBDs in Europe: Similarities to and Differences from Human VBD Emergence Events

14.4.1 Veterinary VBDs: A Primer

Several of the pathogens described already in this chapter are zoonotic: they originate from or circulate within wildlife, companion, and livestock animals, as well as humans. In most cases, however, the zoonotic threat they pose to public health dwarfs the threat to animal welfare, food security and economic security. In contrast with the poverty-trap paradigm, where diseases are a symptom of economic disparities, veterinary VBDs may serve to drive localized poverty through agricultural loss. In this section, we consider some recent outbreaks of VBDs of livestock, focusing primarily on Europe, and we compare and contrast the key policy lessons to those relevant for human VBD outbreaks.

Vector-borne diseases were recognized as a substantial threat to the European livestock and equine industries at a key horizon-scanning event in the 1960s (FAO/OIE 1963). At this event, the 'big three' vector-borne livestock pathogens identified were African horse sickness virus (AHSV), African swine fever virus (ASFV) and bluetongue virus (BTV). African horse sickness virus and bluetongue virus are transmitted by small biting flies in the genus *Culicoides*, commonly called 'midges', but are otherwise epidemiologically 'classical' VBDs rarely transmitted by other routes. In contrast, African swine fever is a highly environmentally-persistent pathogen for which the soft tick vectors (genus *Ornithodoros*) are primarily relevant as a reservoir, contributing a relatively minor force of infection. It spreads readily via environmental contamination including fomites. African horse sickness, as the name suggests, infects equids; bluetongue infects ruminants, and African swine fever infects suids (pigs). All three of these pathogens were first formally described when European settlers introduced 'improved', highly susceptible breeds of livestock into sub-Saharan Africa, where the viruses had each circulated largely sub-clinically in native animals (zebra for AHSV, warthogs for ASFV and various ruminants for BTV) with negligible economic impact.

14.4.2 Social Drivers of Introduction

As with the VBDs discussed elsewhere in this chapter, the frequency with which veterinary VBDs are introduced has increased alongside the increase in international travel and trade over the past decades. These introduction events fall into various classes: the accidental introduction of infected hosts (for example, the introduction of African horse sickness into Spain in 1987 via infected zebra, and the regular introduction of *Leishmania*-infected dogs into Germany (Naucke et al. 2008)), the introduction of infected vectors (either via wind, as with the introduction of bluetongue virus into the UK in 2007, or human transport (Carpenter et al. 2009)) and the introduction of infected materials (the introduction of African swine fever into Portugal as a result of waste from airline flights being fed to pigs near Lisbon airport and the suspected introduction of ASFV into the Black Sea area by food waste discarded from a ship (Stokstad 2017)). The importance of each of these introduction routes is affected by public awareness of their role but also changes in response to changes in public behavior as a result of economic and other social factors. For instance, for other (non-vector-borne) livestock diseases, annual increases in the international movement of live ruminants during religious pilgrimage periods have been recognized as a factor in disease introduction (El-Rahim et al. 2016), and the festival of Eid al-Adha has also been proposed as a possible factor in the emergence of Crimean-Congo haemorrhagic fever in Pakistan (Burki 2012). Recognition of such factors by veterinary authorities may facilitate targeted surveillance or additional support or information services for local veterinarians during high-risk periods.

As well as economic and religious activities, criminal activities may also be a factor in the introduction of important veterinary pathogens, vector-borne or otherwise. Although the initial introduction of African swine fever virus into the Black Sea region is believed to have been accidental, the illegal distribution of contaminated meat from culled animals via wholesale buyers, particularly the military food supply system, have been implicated multiple times in long-distance introduction events (Gogin and Kolbasov 2013).

Socio-political unrest can also be a factor, particularly for pathogens transmitted by ticks which thrive in the high humidity environments afforded by long grass. Pasture in parts of central Anatolia was largely abandoned during the 1990s as a consequence of local terrorist activity; the resumption of farming and hunting was followed by reports of Crimean-Congo hemorrhagic fever virus (CCHFV), and indeed the first ever recognized cases of CCHFV in 1944 followed a similar period of pasture neglect and reoccupation in the Crimea (Hoogstraal, 1979). The emergence of tick-borne encephalitis virus (TBEV) in Eastern Europe also followed the collapse of the Soviet Union and resulting economic and behavioral changes that increased contact rates between hosts and tick vectors (Sumilo et al., 2007).

14.4.3 Social Considerations in the Development and Uptake of Control Measures

The biggest fundamental difference between livestock industries (including, for the purposes of this section, the equine industries) is the economic—and, for horses, social—value of a single animal. This is likely to be a key factor in observed differences in owners' willingness-to-pay for control measures, such as protection from vector attack, vaccination and vector habitat modification. For instance, eliminating contact between vector and host interrupts transmission and is the basis of control strategies such as bed nets and mosquito screening. One equivalent approach for livestock VBDs is the 'Vector-Protected Establishment', which is defined in the OIE Terrestrial Animal Health Code (and derived regional regulations such as EC regulation 1266/2007). European Commission document SANCO/7068/2012 (European Commission 2012) provides guidance on implementing the use of this measure. Although preliminary European studies (Lincoln et al. 2015) have supported the longstanding observation in South Africa (Paton 1863) that stabling can be effective at preventing *Culicoides* attack, the requirements to assure vector protection are quite rigorous, and during the recent emergence of BTV in northern Europe most sites making use of the vector-proof housing regulations have been artificial insemination centers. Engagement with stakeholder groups suggests that the willingness to consider such arrangements would be used much more widely for equids in the event of an outbreak of African horse sickness. This may be partly due to the higher requirement for movement of many such animals, the higher mortality rates seen in most African horse sickness outbreaks, or the higher financial value of the animals, but the social value of companion animals such as horses and dogs is more complex. Another likely example of the effects of perceived social value on control choices was the decision to vaccinate the entire population of California condors (Chang et al. 2007) when West Nile virus appeared likely to arrive in the Western US, despite the cost and unproven safety or efficacy of the vaccine in this endangered species. The social value of this bird is significant, featuring in the culture of several Native American tribes in the region including the Wiyot, Mono, Yokut, and Chumash (Nielsen 2006).

14.4.4 Traditional Farming Practice and Cultural Resistance to Novel Control Strategies

African swine fever was introduced into Europe in Portugal in 1957 and again in 1960. Although it spread to several other countries, it was rapidly eradicated from all locations outside the Iberian peninsula with the exception of Sardinia (Arias & Sánchez-Vizcaíno 2002). However, it was able to persist in parts of Spain and Portugal until the mid-1990s, primarily due to the presence of its soft tick vector/reservoir *Ornithodoros erraticus* (Boinas et al. 2011), which significantly increases the capacity of the virus to persist and is accordingly represented by additional control/quarantine requirements in EU legislation when ticks are suspected to be present (Council Directive 2002/60/EC) (Boinas et al. 2011). The range of these ticks is geographically restricted (Wilson et al. 2013) but even within this range they are predominantly found on farms practicing traditional production methods for the rearing of Alentejano (Iberian black) pigs. Between 1960 and 1990 African swine fever almost destroyed the Alentejano industry (Boinas et al. 2014). However, there is evidence that affordable changes to farming practice such as the adoption of aluminum pig arks for housing (which do not afford resting places for the ticks due to the high temperature they reach during the day) could effectively eliminate tick infestations and significantly reduce the risk from ASFV. Despite this, resistance to modernization among this traditional community remains high. One possible explanation of this is that the market for Alentejano products is relatively high value, low volume, based in part on the social value attributed to traditional farming practices. The Alentejano breed is recognized under the European Union's Protected Designation of Origin (PDO) scheme,[1] which exists to provide consumers with assurance that a product is produced in a specific geographical region using local ingredients and the expertise of local producers. In this case, the resistance of individual farmers to adapting production methods may be a simple economic concern about the risks of moving away from the perception of 'traditional' methods that underlies support for this industry, or it may reflect a cultural preference to this way of life that outweighs the expected benefits of lower-risk farming methods in terms of animal welfare and economic income.

14.4.5 Conclusions and Directions for Future Research

The epidemiology of vector-borne livestock diseases is not simply a function of the distribution of vector or host or of simple environmental factors such as temperature, but arises through differences in population structure, livestock movements, land use patterns and farming practice that may in turn be determined by economic, religious, political or traditional beliefs or behaviors. Attempting to understand recent VBD emergence events in or close to Europe and affecting or involving livestock without appreciating the role of these factors reduces our capacity to understand and mitigate them, to predict future emergence risks, and to develop and effect-

[1] https://tradicional.dgadr.gov.pt/en/categories/meat/pig-meat/366-carne-de-porco-alentejano-dop-en

ively deploy appropriate control strategies. The political, economic, cultural, and psychological factors that must be considered when developing management strategies for VBDs in animal systems mirror those involved in transmission cycles that include humans. While veterinary VBDs are an important focus of research in their own right, they may also serve as model systems for better understanding the complexity of human VBDs, providing insights into leverage points for intervention.

14.5 Summary

In this chapter, we explored how social processes in systems may shape drivers or contexts for vector-borne diseases. We used three contrasting systems to illustrate that a poverty-trap framing may generalize the issues complicating VBD control, in the face of history, politics, intervention successes and failures, natural and unnatural disasters, behaviours, perceptions, practices, and financial interests in control, independent of those receiving it. Vector-borne diseases have far larger and more intricate social lives than can be captured by current health management frameworks. While it can be beneficial to use existing frameworks to leverage attention and assistance (e.g. labels such at NTDs, or framing as a poverty-related issue for aid purposes), as we have described here, our frameworks do not capture the range of underlying socioeconomic scope, and political context. It is therefore essential that the instruments of social science research, the recognition of political history, understanding of local context, and the framing of the system, be integral parts of VBD research and intervention practice.

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