The art of medicine

Aedes aegypti suppression in the Americas: historical perspectives

Today populations in the Americas are under increasing threat from the dengue, chikungunya, and Zika viruses, spread by the *Aedes aegypti* mosquito. In earlier centuries, the same mosquito spread the deadly haemorrhagic viral infection known as yellow fever. Rigorously organised vector control programmes in the 20th century, however, ended the urban cycle of yellow fever in the Americas. This historic public health success has relevance for the current public health crisis.

The *A aegypti* mosquito arrived in the Americas on the slave ships that transported African captives to the Americas, as did the yellow fever virus. The first epidemic of yellow fever—with its signature symptom of black vomit—exploded in the mid-17th century in the Caribbean. Thereafter, *A aegypti* sporadically ignited haemorrhagic yellow fever epidemics that ravaged military encampments and coastal cities.

In the late 19th century, the Cuban physician Carlos Finlay proposed that a mosquito was the vector for yellow fever, and at the turn of the 20th century, the US Army's team of medical investigators in Cuba, led by Walter Reed, discovered that *A aegypti* was indeed the culprit. It was a domesticated mosquito that bred in man-made containers that capture rainwater. In 1901, the US military began rigorous campaigns to destroy its breeding sites in dense urban areas that were thought to be "seedbeds" of infection. The success of the early efforts was remarkable. Yellow fever was eliminated from Havana and other Cuban port cities and the Panama Canal Zone in the first decade of the 20th century.

Others took inspiration. In 1903, Oswaldo Cruz, the Brazilian Director-General of Public Health, began a campaign in Rio de Janeiro that, by 1909, had reduced yellow fever deaths there to zero. In 1916, the Rockefeller Foundation created a Yellow Fever Commission, which determined that Guayaquil in Ecuador was a centre of endemic infection, and eliminated yellow fever deaths there within 2 years.

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American epidemiologist Fred L Soper (centre) with Brazilian President Getúlio Vargas (left) in 1940

Some gains, however, proved impermanent. In 1928, a yellow fever outbreak in Rio de Janeiro and in a few Brazilian towns and settlements outside of the main urban areas forced a reassessment of vector control strategy. Beginning in 1930, with financial support from the Rockefeller Foundation, the Brazilian dictator Getúlio Vargas authorised a military-style programme of larval source reduction that compelled city and town dwellers to destroy breeding sites on their properties, imposed fines for non-compliance, and required the post-mortem extraction of liver tissue samples from individuals whose deaths were suspected to have been caused by yellow fever, in an effort to better understand the spatial epidemiology of the outbreaks.

Fred Soper, a Rockefeller Foundation health official, spearheaded the Brazilian initiative, which focused on the suppression of *A aegypti* in urban areas and eliminated the mosquito in several cities. Soper and his colleagues discovered, however, that there was a primate reservoir of the virus in the South American rainforests transmitted by a different genus of mosquito. Although they realised that they could not stop the sylvatic cycle, this did not stem their commitment to vector control. They expanded their efforts and eliminated *A aegypti* throughout most of Brazil, and their major challenge became the prevention of the introduction of the mosquito from neighbouring states. Soper and his team reached this milestone before the era of synthetic residual insecticides. They secured the gains by administering the Rockefeller Foundation's 17D yellow fever vaccine to urban populations. In 1938–39, Soper and his co-workers undertook a separate vector control campaign to suppress a non-domesticated malaria mosquito *Anopheles gambiae sensu lato* (*Anopheles arabiensis*) which had been introduced into northeastern Brazil from west Africa. They eliminated it. During World War 2, Soper helped to launch an elimination project in Egypt against an *A gambiae sensu lato* mosquito introduced from sub-Saharan Africa and it achieved full success by 1945.

In the immediate post-war era, DDT became available for larval suppression. In 1947, Soper was elected Director of the Pan-American Sanitary Bureau, and the member states agreed to eliminate *A aegypti*—even though there had only been one urban outbreak of yellow fever in the Americas in the preceding 15 years. In 1955, the World Health Assembly ratified a programme for global malaria eradication that was based upon the use of synthetic residual insecticides. By 1964, the malaria programmes had reduced malarial infections to small numbers. In the same year, a full victory against *A aegypti* and urban yellow fever seemed at hand. Brazil and most other

states in Central America, South America, and the Caribbean had eliminated *A aegypti* from their national territories.

Not all signatories, however, were fully engaged. Some of the Caribbean states led faltering programmes. The USA did not begin field operations until 1964, preferring to require certificates of yellow fever vaccination from returning travellers and stockpile vaccine for use in the event of an outbreak. After 2 years of effort, however, the elimination of *A aegypti* in the USA seemed at hand. But then the US programme came to an end. David Sencer, Director of the Centers for Disease Control and Prevention, thought the hemispheric campaign could not succeed without a global commitment to the eradication of *A aegypti*. Moreover, insecticide resistance was emerging as an operational problem in both the anti-malaria and *A aegypti* elimination campaigns, and Rachel Carson's blockbuster *Silent Spring* (1962) was raising popular awareness of the dangers of the profligate use of DDT in agriculture. As the USA backed away from *A aegypti* elimination, other countries abandoned their efforts. *A aegypti* eventually recolonised and expanded its former range. Had the elimination efforts been continued to completion and reinforced with a system of surveillance, the Americas might have had good intelligence about the early phases of the hemispheric invasion by *Aedes albopictus*, the Asian tiger mosquito which can transmit the same pathogens, and been able to undertake timely countermeasures.

During the 1980s, as dengue infections burgeoned in the Americas, affected nation states began to spray synthetic residual insecticides to reduce mosquito densities. In the 1990s, as dengue spread, the insecticides began to be deployed to cover large community areas using ultra-low volume spray from aeroplanes and ground vehicles, but the efforts did not prove highly effective and promoted insecticide resistance. In 1997, 50 years after its initial agreement for the hemispheric eradication of *A aegypti*, the Pan American Health Organization (successor to the Pan-American Sanitary Bureau) re-endorsed the concept of *A aegypti* elimination but not all member states committed to this programme, and the initiative stalled. National spraying programmes continued. Beginning in 2011, Brazil began to experiment with the release of genetically modified male mosquitoes in some major urban areas. In 2016, facing the increasing threat from the Zika virus, Brazil has launched a vector control programme staffed by military and civilian personnel. It, too, is based principally upon the spraying of residual insecticides.

In the early and mid-20th century, the vector suppression programmes mobilised support based on the perception of the threats from urban yellow fever and malaria. The efforts were rigorous and nearly conclusive. In the late 20th and early 21st centuries, the vector suppression programmes—based on the perception of risk from dengue—have been less effective. Today, the combined risks from potential yellow fever transmission and ongoing transmission of the dengue, chikungunya, and Zika viruses might well encourage a return to an aggressive approach of hemispheric vector suppression and elimination. It need not, however, be guided by an authoritarian impulse. The contemporary malaria elimination campaign suggests an alternative model. Its goal is the elimination of malaria within national territories, along with surveillance to extinguish outbreaks in the event of reintroductions. The malaria campaign's *modus operandi* in reducing infections—to deploy a wide range of imperfect tools in different combinations in different settings—might be taken as a source of inspiration. Its progress in reducing morbidity and mortality is powered in part by the ongoing financial commitments of the Global Fund, the US President's Malaria Initiative, and the Bill & Melinda Gates Foundation.

Today, there is a fully effective vaccine against yellow fever and a partially effective vaccine against the dengue viruses, although many populations remain unprotected. Vaccines against chikungunya and Zika seem at best to be some years in the future. The historical epidemiology of interventions against the arboviruses spread by mosquitoes in the Americas suggests that, even should vaccines eventually become available for chikungunya and Zika, vector suppression and active surveillance will remain of central importance.

Past successful efforts to suppress and eliminate *A aegypti* suggest that such achievements might be realised again. Some of the main arguments raised against a new initiative to undertake species elimination are that the Brazilian campaigns of the 1930s and 1940s depended upon coercion, the urban populations today are far larger, the campaigns of the late 1940s to 1960s in the Americas depended upon DDT, and the volume of global trade, particularly in used tyres—a common breeding site of *A aegypti* and *A albopictus*—is much greater than in the past. The historical epidemiology of *A aegypti* suppression in the Americas should be investigated closely. It may be that the main constraints to effective vector control in the post-1960s period were financial and political rather than technical. Today, a broader array of vector control tools is available, and others could likely be developed, as well as new means of engaging in collaborative ways the populations affected by mosquito-borne viruses. A major commitment by philanthropic and international organisations with a vision of hemispheric vector control could tip the balance toward more effective suppression and disease control. With the threat of urban yellow fever lurking in the rainforests, and an escalating threat of chikungunya, dengue, and Zika transmission, there is a long and potentially instructive history of more than 100 years of vector control to draw upon when considering future prospects to control *A aegypti* and *A albopictus*. Some elements of this history of vector suppression and elimination are cautionary; others are strongly encouraging.

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Further reading

Gubler, DJ. The changing epidemiology of yellow fever and dengue, 1900 to 2003: full circle? *Comp Immunol Microbiol Infect Dis* 2004; **27:** 319–30

McNeill JR. Mosquito empires: ecology and war in the greater Caribbean, 1620–1914. New York: Cambridge University Press, 2010

Soper, FL, Wilson DB, Lima S, Atunes WA. The organization of permanent nation-wide anti-*Aedes aegypti* measures in Brazil. New York: The Rockefeller Foundation, 1943

Soper FL. The elimination of urban yellow fever in the Americas through the eradication of *Aedes aegypti*. *Am J Public Health* 1963; **53:** 7–16

Stepan NL. Eradication: ridding the world of diseases forever. Ithaca: Cornell University Press, 2011