Mosquitopia? The Place of Pests in a Healthy World

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Presenters

Conveners

- Marcus Hall, environmental historian, University of Zurich/Rachel Carson Center
- Dan Tamir, political/environmental historian, University of Zurich/Ben-Gurion University

Other participants

- Samer Angelone, wildlife biologist and videographer, Zurich
- Ulrike Beisel, human geographer, University of Beyreuth
- Romeo Bellini, medical entomologist, Agricultural and Environmental Center (CAA), Bologna
- Clara Bermúdez-Tamayo, health economist, Andalusian School of Public Health
- Christoph Boete, evolutionary biologist, University of Montpelier
- Peter Coates, environmental historian, University of Bristol
- Isabelle Dusfour, medical entomologist, Pasteur Institute-French Guiana
- Adriana Ford, socio-ecosystems scientist, Imperial College London
- Melissa Graboyes, medical ethicist and historian, University of Oregon
- Frances Hawkes, medical entomologist, University of Greenwich
- Helmut Lemke, artist on WetlandLIFE project, UK
- Christof Mauch, environmental historian, Rachel Carson Center
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- Alex Nading, anthropologist, Watson Inst. for International and Public Affairs, Brown U.
- Ramya Rajagopalan, bioethicist, University of California, San Diego
- Luísa Reis-Castro, historian and anthropologist of science, MIT
- Frédéric Simard, mosquito population geneticist, IRD Montpelier
- Nancy Leys Stepan, medical historian, Columbia University
- Willem Takken, insect ecologist, University of Wageningen
- Ken Vernick, insect vector geneticist, Pasteur Institute-Paris
- Eva Veronesi, medical entomologist, University of Zurich
- Jim Webb, health historian, Colby College
- Anna Wienhues, environmental ethicist, University of Zurich

Detailed Abstracts

Marcus Hall (environmental historian, Rachel Carson Center / University of Zurich)
& Dan Tamir (political & environmental historian, University of Zurich)

Killing Mosquitoes? The Pros and Cons (a first draft)

Global warming is ushering us into a new mosquito epoch. Ready or not, mosquitoes are coming faster than before, both indigenous and non, disease-carrying and not, human-biting and not. What are we to do with these buzzing creatures, and what has been done with them? Are we able to control, or locally exterminate them, and with what side effects? Or is it more realistic to admit that *Aedes*, *Anopheles*, and *Culex* are really controlling us? Even if malaria mortality has been dropping in past years, malaria morbidity still pervades the globe, with half of humanity still exposed to this and other dangerous mosquito-carried diseases, from dengue to West Nile, from yellow fever to Zika,. Control them we should, we must do, if we are to survive our mosquito-borne Anthropocene.

But there are important reasons to protect mosquitoes, and not just because these are amazing products of co-evolution – since protecting them may in some instances assist us in the battle against human disease. Most obviously, we may need to save mosquitoes for the simple reason that one needs to preserve some of them in order to figure out how to kill the rest of them. Yet more subtle justifications for saving mosquitoes center, for instance, on food web dynamics, whereby in our efforts to poison these creatures, or disrupt their habitat, or rearrange their DNA, we may through ecological loops actually cause damage to other biological entities, such as mosquito predators, and end up *increasing* mosquito fitness and their ability to multiply and spread across the earth. Perhaps the sciences of mosquito control, or certain sectors of them, have not yet advanced to a stage that we can trust.

Some years ago, *Nature* journalist Janet Fang posed the simple question about what the ecological consequences might be of eradicating mosquitoes.[1] After all, a concerted campaign across the 20th and 21st centuries has been dedicated to this very goal. In sifting through the evidence, Fang's main answer is that in the case of this blood-sucking insect, humanity and even ecosystems could probably get along just fine without it. She reports on the views of one ecologist who feels that mosquitoes could readily be replaced in the food web, with many mosquito predators eventually able to switch to moths or other sources of food, for example. Although she outlines a host of possible disruptions stemming from the disappearance of mosquitoes, such as the loss of their pollination activities and other ecosystem services, she concludes by quoting entomologist Joe Conlon who feels that ecosystems "will hiccup and then get on with life. Something better or worse would take over." As Conlon elaborates in his own blog, "I would rather eat raw onions and celery for the rest of my life if I could do away with the little bastards."

Below we highlight some of the main arguments for saving mosquitoes, before reminding ourselves of crucial reasons for setting out to control and eradicate them. Ours is not a comprehensive list, and our main goal here is to stimulate participants of our symposium to identify other, and perhaps more important reasons for dealing with the question of how far we can, or should be pursuing the

[1] Fang, J. 2010. "A World Without Mosquitoes," *Nature* 466:432-4; Conlon, J. 2011. "Mosquito genocide," *Nothing But Science* at https://nothingbutscience.wordpress.com/tag/joe-conlon/ on 28.5.19.

goal of mosquito elimination. We seek the collective insight of all the talent gathered at our symposium, and invite everyone to search for ideas even beyond one's own discipline.

A few reasons for saving mosquitoes:

Strategic: We must remind ourselves that we are ultimately battling disease, not mosquitoes, and that there may be more effective, more economical, more ethical ways to do this than mosquito control. Malaria once emanated from swamps, and bad air, though with more evidence it became clear that mosquitoes were the vectors of this disease. Should we be putting greater efforts into battling the plasmodia pathogens rather than the carriers of them? Should we be focusing at still smaller levels, such as on the chemicals set in motion by the pathogens? Zoologist Marston Bates once called DDT the "sledge-hammer approach to mosquito control" since DDT caused so much collateral damage to other living things, from birds and fish to desirable insects such as bees.[2] Early anti-malarial medications such as Atrabrine was itself a sledge-hammer approach in human blood streams, since people felt pretty nauseous after taking this medication. Because there are pros and cons to every remedy, then we need to return to cost-benefit analyses, before marching forward with any one remedy.

Medical: Another issue focuses on the importance of maintaining discrete, residual levels of pathogens in a population so as to maintain an epidemiologic signal that our bodies can react to and maintain resistance against. When malaria was largely eradicated from parts of Madagascar, only to return five years later, it returned with atypically dangerous virulence. Maintaining some mosquitoes, and so the disease, means that human physiologies would not become naively adapted to a malaria-free environment. A related issue is that certain kinds of less dangerous malaria can provide protection from more dangerous malaria: a person infected by *Plasmodium vivax* is given some protection from being infected by more dangerous *Plasmodium falciparum*. As a protective measure, humans could theoretically be artificially inoculated with *P. vivax*, yet mosquitoes will inoculate them for free.

Ecological: There are many ecological arguments that point to the beneficial role of mosquitoes in ecosystems. Metric tons of flying biomass certainly alter natural processes, whether as foodstuff for other organisms or modifiers of animal behavior, as in the case of caribou and *Homo sapiens* who move to avoid them. There are the parasites and pathogens carried by mosquitoes which infect not only humans, but also many other mammals, as well birds and reptiles. Microbes transmitted by mosquitoes to bats helps control numbers of bats, and so control the spread of human diseases propagated by bats. Some mosquitoes even control other species of mosquitoes, since certain adult species feed on larvae of other species.[3] These mosquito-borne benefits are therefore good reasons for maintaining mosquitoes in ecosystems, or bringing them back if overly controlled.

Evolutionary: Parasites and hosts coevolve, sometimes with beneficial results for both, as each generally become more tolerant of the other through time. Or at least this is Joshua Lederberg's argument for why the virulency of parasites can diminish through time.[4] Cautious hands-off approaches to vector control therefore allows nature to take its course, with harmful results balanced increasingly by beneficial ones. In short, there are crucial long-term roles for our bodily symbionts, and human interferences in their transmission may produce more harm than good.

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[2] Marston Bates in J. Logan. 1954. *The Sardinian Project* (Baltimore: Johns Hopkins U. Press), x.
[3] O. Roux and V. Robert, "Larval predation in malaria vectors and its potential implication in malaria transmission: an overlooked ecosystem service?," *Parasites & Vectors* 12: 217.
[4] Joshua Lederberg [1993] quoted at Pierre-Olivier Méthot, "Why do Parasites Harm Their Host? On the Origin and Legacy of Theobald Smith's 'Law of Declining Virulence,'" *History and Philosophy of the Life Sciences* 34 (2012), 567.

Ethical & Social: On a more fundamental level, do humans have the right to kill, or exterminate other creatures – even the right to transform or disrupt whole ecosystems? Is it justifiable to act when we are still quite unsure about how all an ecosystem's pieces fit together? If we are placing ourselves at the top of the pyramid of creation, what does that tell us about ourselves and our place in the future? We have to date, never been able to rid the earth of mosquitoes despite dogged efforts to do so: What makes us think we can do so now? Hubris has been the rule, not the exception in the history of humanity. Yet is it even thinkable that humans have the right not to seek every means possible to control and curtail disease-spreading organisms? Can it be fair to pay more attention to insects than to humans made sick by them? And is it right to rely on expert opinion, when the individuals directly affected by anti-mosquito treatments have different viewpoints?

Economic: Millions of funds and thousands of researchers are now dedicated to vector control and research for vector control. In terms of spending efficiency, should these limited resources be dedicated to other measures, such as bed nets, tighter houses, better equipped hospitals, and health education? Mosquito control is one of many health measures, and perhaps one of lesser priority depending on circumstance. An ongoing challenge is to focus on effective resource allocation, which may change by the year. Another economic issue focuses on the potential utility of mosquitoes to science or medicine; for example, mosquitoes can detect miniscule quantities of C02, and produce amazing anti-coagulants, with both traits suggesting entrepreneurial opportunities, unless these are curtailed by exterminators.

Aesthetic: Insects in general, and mosquitoes in particular, are exquisitely engineered organisms, marvelously adapted to their various roles, and elegantly effective in carrying them out. We cannot help but admire them, even paint them, sculpt them, and marvel at their buzzes. Mosquitoes manage to pair with each other by harmonizing the frequencies of their beating wings, and artists can amplify and project these harmonic sounds.[5]

Key reasons for killing mosquitoes:

Human health: First and foremost, despite the many and important reasons for saving mosquitoes, or at least saving certain mosquitoes under certain situations, there remain dire needs to eradicate these creatures, undertaking extreme measures to accomplish this goal. A crucial reason why mosquito-borne diseases are not more pervasive today is that former mosquito controllers were reasonably successful in their goals, bringing mosquito numbers down long enough so that the pathogens they carried dropped below threshold levels. Pandemic mosquito-borne diseases, stemming from transmitted virus, bacteria, and protozoa, are not as dangerous today as they were a century ago, due in good measure to successful anti-mosquito campaigns waged around the world.

Pragmatic: It should be pointed out that killing mosquitoes allows us to avoid other, undesirable health (and economic) consequences when dealing the resulting diseases, such as ingesting nauseating medications. Malaria-exposed soldiers and civilians during World War II sometimes avoided taking their prophylactic Atabrine altogether because of the sickening side-effects of this drug.[6] Finding a magic bullet that removes mosquitoes from ecosystems may therefore have

[5] "Built-in sound amplifier helps male mosquitoes find females," Science Daily (2018), at https://www.sciencedaily.com/releases/2018/09/180925110014.htm on 30.5.29. See also: http://robinmeier.net/?p=38 (thanks to Peter Coates for alerting me to this source).

[6] M. Hall. 2010. "Environmental Imperialism in Sardinia: Pesticides and Politics in the Struggle Against Malaria," in *Nature and History in Modern Italy*. M. Armiero & M. Hall, eds. Athens: Ohio University Press: 70-86.

ulterior beneficial consequences beyond curtailing disease, including the ability to redirect resources from healthcare to other crucial services. Systematic sterilization of mosquitoes would also allow wetlands to continue being wet, for example, since draining them would no longer be required to disrupt mosquito habitat.

Ecosystem management: From another perspective, our human-altered biosphere means that mosquito numbers and their distribution are no longer natural, no longer in balance, so that human action is required to bring those balances into better harmony. Here, Stewart Brand's dictum that "We are as Gods, and may as well get good at it" holds true for mosquito management. After Europeans settled in certain areas of coastal South Africa, massive mosquito swarms arose where they were once rare: one explanation is that newly erected metal rooves concentrated rainfall into puddles, thereby multiplying mosquito habitat and so mosquito-borne disease. A rationale human response would therefore aim at resetting environmental equilibria, seeking to recreate proper mosquito balance. Such an argument can be used for justifying efforts to exterminate invasive alien Tiger mosquitoes (*Aedes albopictus*) that never used to buzz across the Americas and across Europe, but are now propagating at least 20 threatening diseases.[7] Altering stream ecology by introducing Gambusia fish for slurping up mosquito larvae may be part of the necessary quest to re-engineer the earth.

Comfort: Ridding *non*-disease carrying mosquitoes would likewise bring human benefits. Pesky mosquitoes drive people inside or away from their favorite places. In those areas where yellow fever or dengue, say, are not a threat, the act of removing blood-thirsty insects would seem a good reason to continue funding mosquito-control agencies. After all, clearing mosquito swarms allows other organisms easier access, including humans. Coastal wetlands, as in New Jersey, were virtually uninhabitable until early 20th-century drainage measures decimated mosquito populations and brought land values up.[8]

The case for killing or else conserving mosquitoes goes to the core of what it means to be human in the natural world. The above points offer just a sampling of the reasons for supporting either side of this question, and certainly there are many other reasons to be added. We hope that you can highlight some of the other reasons that we have not mentioned – or expand on the points we have touched on. How we interact with, show mercy for, declare war on, or learn to live with our most dangerous game becomes a parable of our future on this planet. We believe that Mosquitopia is that state of balance that can permit us to survive into the next epoch.

[7] S. Bhaumik. 2013. Aggressive Asian tiger mosquito invades Europe. CMAJ. 185 (10): E464-4.
[8] G. Patterson. 2009. The Mosquito Crusades: A History of the American Anti-mosquito Movement. New Brunswick: Rutgers University Press, p.83.

Samer Angelone (filmmaker and wildlife biologist, Zurich).

Scientists have the tendency to communicate their scientific accounts using linearly structured narratives (Introduction, Methods, Results and Discussion; IMRAD). Likewise, the linear narrative is dominant – due to force of habit – when scientists prepare films about their research. Yet, this does not necessarily have to be the case for the new generation of *scientists-as-filmmakers*, who is trained to appreciate and apply alternative narrative structures. For this symposium, I will be exploring how film can offer novel and creative ways to show the promises and perils of mosquito control.

Uli Beisel (medical and human geographer, University of Beyreuth)

Disappearance, Invasion and Resistance: Trajectories of Insect Control and Loss in Ghana and Germany

Germany seems to be abound with insect-related debates these days. On the one hand, the *Aedes albopictus*, Asian Tiger mosquito, is slowly but surely establishing a habitat along the motorway A5 in Southern Germany. On the other, a study of an entomological volunteer organisation in Krefeld that was published in late 2017 has brought world-wide attention to the phenomenon of starkly diminishing insect biomass. Meanwhile in West Africa insecticide tolerance is spreading and threatening well-established control strategies against *Anopheles* mosquitoes, such as mosquito nets or indoor residual spraying with insecticides. This talk connects my long-standing anthropological fieldwork on mosquito control in Ghana with the recent developments in Germany. Discussing mutating mosquitoes in West Africa, invasive mosquitoes in Germany, and current indications of starkly diminishing insect biomass around the world together, I suggest allows us to bring concerns in health and ecology in conversation and tension with each other. Ultimately, I ask how humans can learn to live together with organisms we- on the one hand- depend on, and who can –on the other hand- be harmful to our health?

Romeo Bellini (medical entomologist, CAA Bologna)

Mosquito elimination? We may start from restoration.

As a vector ecologist working on mosquito borne diseases since many years now, I am fascinating by the promises that new technologies such as gene drive are proposing to our attention. Because the subject is raising a number of questions that we cannot answer with the support of data, there is a lot of space for speculation and intellectual controversy. To better drive the discussion, I'd suggest to narrow the analysis on just one species, let's say *Aedes aegypti*. Population' geneticists will explain us that we have diversity inside one species, which make things more complicated on one side and perhaps less risky on the other side. I may also see another possible way to approach the question. In recent time, mainly due to the globalization of transport, we have seen several mosquito species invading new territories, thus influencing ecology, public health and human society. These invading populations being certainly less adapted in comparison with the long term adaptation to the original environments are probably more vulnerable and their eventual elimination will bring to the restoration of previous settings.

Clara Bermúdez-Tamayo (health economist, Andalusian School of Public Health)

Impact, Economic Evaluation, and Sustainability of Integrated Vector Management to Prevent Vector-Borne Diseases

Introduction. The control of vector-borne diseases (VBD) is one of the greatest challenges on the global health agenda. Rapid and uncontrolled urbanization has heightened the interest in addressing these challenges through an integrated vector management (IVM) approach. IVM use both chemical and non-chemical methods, including environmental managemen. It is part of a comprehensive strategy encompassing a variety of other vector control methods, such as collaboration with the health sector and other sectors, educational campaigns, advocacy, social mobilization, evidence-based decision making, and capacity building. The aim was to identify components related to impacts, economic evaluation, and sustainability that might contribute to this integrated approach to VBD prevention.

Methods. We conducted a scoping review of available literature (2000–2016). A data extraction form was used, including TIDieR and ASTAIRE. MMAT and CHEERS to evaluate quality.

Results. Of the 42 documents reviewed, 30 were focused on dengue, eight on malaria, and two on leishmaniasis. More than a half of the studies were conducted in the Americas. Half used a quantitative descriptive approach (n=21), followed by cluster randomized controlled trials (n=11). Regarding impacts, outcomes were: a) use of measures for vector control; b) vector control; c) health measures; and d) social measures. IVM reduced breeding sites, the entomology index, and parasite rates. Results were heterogeneous, with variable magnitudes, but in all cases were favourable to the intervention. Evidence of IVM impacts on health outcomes was very limited but showed reduced incidence. Social outcomes were improved abilities and capacities, empowerment, and community knowledge. Regarding economic evaluation, only four studies performed an economic analysis, and intervention benefits outweighed costs. Cost-effectiveness was dependent on illness incidence. The results provided key elements to analyze sustainability in terms of three dimensions (social, economic, and environmental), emphasizing the implementation of a community-focused eco-bio-social approach.

Conclusion. IVM has an impact on reducing vector breeding sites and the entomology index, but evidence of impacts on health outcomes is limited. Social outcomes are improved abilities and capacities, empowerment, and community knowledge. Economic evaluations are scarce, and cost-effectiveness is dependent on illness incidence. Community capacity building is the main component of sustainability, together with collaboration, institutionalization, and routinization of activities. Findings indicate a great heterogeneity in the interventions and highlight the need for characterizing interventions rigorously to facilitate transferability.

REFERENCES:

- Marcos-Marcos J, Olry de Labry-Lima A, Toro-Cardenas S, Lacasaña M, Degroote S, Ridde V, Bermudez-Tamayo C. Impact, economic evaluation, and sustainability of integrated vector management in urban settings to prevent vector-borne diseases: a scoping review. Infect Dis Poverty. 2018 Sep 3;7(1):83.
- Dagenais C, Degroote S, Otmani Del Barrio M, Bermudez-Tamayo C, Ridde V. Establishing research priorities in prevention and control of vector-borne diseases in urban areas: a collaborative process. Infect Dis Poverty. 2018 Sep 3;7(1):85.
- Bermudez-Tamayo C, Mukamana O, Carabali M, Osorio L, Fournet F, Dabiré KR, Turchi Marteli C, Contreras A, Ridde V. Priorities and needs for research on urban interventions targeting vector-borne diseases: rapid review of scoping and systematic reviews. Infect Dis Poverty. 2016 Dec 1;5(1):104.

Christoph Boete (evolutionary biologist, University of Montpellier)

Gene drive and the extinction of mosquitoes: Between hype and reality

There has probably never been so much discourse about the potential extinction of one or several mosquito species able to transmit malaria since the advent of gene drive technology. Whether associated with the idea of removing a wild species (population suppression) or replacing it by a 'non-wild' genetically-modified non-vector one (population replacement), never in previous attempts at eradicating malaria or eliminating the disease from a large area, the issue of extinction and the related concerns have arisen so strongly. By reviewing and analysing the communication around the so-called promises of this technology in relation with its numerous limitations, my aim is to address the question of hype in which gene drive approaches are embedded. By doing this, I am also willing to discuss how such approaches could affect the perception of what would become your future relationships with mosquitoes.

References of interest:

Caulfield, T. & C. Condit. 2012. Science and the sources of hype. Public Health Genomics. 15(3-4): 209-17. doi: 10.1159/000336533.

Crisanti, A. & K. Kyrou. Using gene drives to control wild mosquito populations and wipe out malaria. The Conversation. Dec. 21, 2018. (http://theconversation.com/using-gene-drives-to-control-wild-mosquito-populations-and-wipe-out-malaria-104613)

Wade, N. Giving Malaria a Deadline. Sept. 24, 2018. The New York Times. (https://www.nytimes.com/2018/09/24/science/gene-drive-mosquitoes.html)

Reilly, M. In Africa, scientists are preparing to use gene drives to end malaria. MIT Technology Review. Mar. 14, 2017. (https://www.technologyreview.com/s/603858/in-africa-scientists-are-preparing-to-use-gene-drives-to-end-malaria/)

Peter Coates (environmental historian, University of Bristol)

JUST A TROUBLESOME NUISANCE?

'Caribou' and 'comfort' are the two words from Marcus and Dan's 'Position Statement' that buzzed most loudly in my ears. Their example of how mosquitoes govern animal behaviour jumped out at me because the first time I gave any serious thought to the 'little bastards' was as a hitchhiking graduate student, headed for Alaska's Arctic coast. In early summer, pregnant caribou trekking northward to their birthing grounds on the boggy coastal tundra are so tormented that the search for relief (lower temperatures and stronger winds) can drive them into the sea itself. The potential mosquitoes possess en masse to kill a new-born caribou calf is a salutary reminder that mosquitoes do not have to carry deadly disease to be lethal. Though they claim the occasional human death from septicaemia when a bite gets infected, these mosquitoes, however annoying and inconvenient, are technically non-lethal.

My symposium contribution targets the discomfort so-called nuisance (pest) mosquitoes cause, especially in Britain (which is rarely associated with mosquitoes after the withering away of its native strain of malaria, ague, by the early 20th century). A wealthy Brit founded the British Mosquito Control Institute (1920) because they harassed tennis playing and cucumber sandwich-eating guests at his seaside villa. The challenge of the party-pooping mosquito may seem trivial in comparison with the life and death struggle against the malarial mosquito. But early 20th century efforts to control and eliminate nuisance mosquitoes inhabiting Britain's coastal wetlands for the sake of human comfort (and profit) paralleled attempts to expand human lebensraum and wealth-creation opportunities – which Marcus and Dan flag up - in US states like New Jersey. We should not underestimate the amount of human energy that northern Europeans and North Americans have expended in combatting the nuisance value (ecosystem disservice?) of the kind of mosquito that Ronald Ross's characterized as 'at first sight…a wholly insignificant creature'.

Readings

Hogarth, A.M. *British Mosquitoes and How to Eliminate Them* (London, 1928)
Marshall, J.M., *Principles and Practice of Mosquito Control* (Hayling Island, 1928)
Anderson, R., 'The Arctic mosquito swarms large enough to kill a baby caribou', *The Atlantic*, 16 September 2015, https://www.theatlantic.com/science/archive/2015/09/arctic-mosquitoes-and-the-chaos-of-climate-change/405322/

See also: http://www.wetlandlife.org/latest/30-pursuing-british-mosquitoes-into-the-archives

and: http://www.wetlandlife.org/latest/52-introducing-mosquitoes-from-the-temperate-world-to-the-tropics-or-from-hampshire-to-haiti-and-from-portsmouth-to-panama

Isabelle Dusfour (medical entomologist, Pasteur Inst., Paris)

How could we rethink control of arboviral diseases?

Mosquito control has for objective to reduce biting rate to humans with the expected outcomes to prevent and control the spread of diseases caused by pathogens they transmit, or reduce nuisance. Up to now, source reduction and insecticide use have been the main tools to fight disease spread. Pest control is also implemented with the same tools but often set-up separately, increasing the risk of insecticide resistance development in vectors. For decades, massive sprays have been operated but the real efficacy of those methods to control outbreaks can be discussed while environmental consequences are pointed-out. In addition, indicators that trigger interventions should also be debated and improved.

Integrative approach had been the first step to improve mosquito control, reduce unintentional impact of insecticides and engage populations for their health. However, the perception of mosquitoes by human populations may not be what is expected. Years of community-based strategies have demonstrated the difficulties to correctly educate and raise awareness on mosquitoes and diseases in order to mobilize in action and to sustain population engagement.

In recent years, control of transmission is facing novel challenges with the emergence, re-emergence and spread of arboviruses implicating different mosquito species. Novel technologies provide a larger panel of tools but also need to prove epidemiological efficacy and be accepted by populations.

Every methods and strategies have proven some efficacy and eventually limitations. Other angles have to be thought to anticipate the risk of transmission. Methods or strategies more respectful of environment, more specific, accepted by population and manageable need to be deployed to reduce transmission. Aren't we talking of utopia?

Adriana Ford (socio-ecosystems scientist, Imperial College London)

Local perceptions towards mosquitoes and mosquito risk in English wetlands

Malaria, once known as ague, was endemic in Britain from the 15th century and was often associated with wetland areas –'*marsh fevers'*, attributed to '*the noxious vapours of stagnant mashes*' (Dobson 1989 p3). In the first half of the 20th century, prominent scientists at the British Mosquito Control Institute on Hayling Island facilitated research and public consciousness around the '*gravity of the menace'* of the British mosquito (Hogarth 1928). However, with ingenious malaria eradicated from the island in the mid 20th century, attention declined towards mosquitoes as a British problem. Yet now, in the 21st Century, as increasing global temperatures facilitate the spread of mosquitoes and mosquito-borne diseases in other parts of Europe (Semenza and Suk 2018), combined with tabloid headlines designed to provoke fear and panic (e.g. Swain 2012, Daily Mail, 2019), wetlands and their mosquitoes may once again be viewed with anxiety. Mosquitoes in Britain are monitored by public health authorities such as Public Health England (e.g. Vaux and Medlock 2015), but little is known about the perceptions towards mosquitoes in countries, such as the UK, where mosquito-borne diseases are only a possible risk and not yet (or nor longer) a reality. Are mosquitoes on people's consciousness as a native pest and cause for concern? Might perception towards mosquitoes affect wetland management, restoration and creation?

Within a broader exploration of the values of English wetlands from a health and wellbeing perspective, we used Community Voice Method (a participatory social sciences research method using filmed interviews and documentary making) to investigate experiences and perceptions towards mosquitoes as a British wetland pest. Fifty-six participants (farmers, reserve managers, volunteers, walkers, bird watchers, and other recreational wetland users and local residents) from three sites of different wetland typologies in England (in Somerset, Bedford and the Humber), provided a snapshot into experiences and perceptions of these infamous insects in a very local context. Reported experiences ranged from no interaction with mosquitoes on the wetlands at all, through to, in one case, keeping their children under mosquito nets, and whilst perception towards mosquitoes themselves and mosquito risk (either as a nuisance or a disease vector) also varied, there was no real sense of alarmism or panic for the future, with often pragmatic responses to the possible risks. These attitudes can be considered not only in relation to the future of mosquitoes and their management in Britain, but also the future of wetland management, and the balance between the multiple benefits provided by these diverse habitats with the possible challenges that may or may not materialise in the future.

Readings:

Daily Mail (2019) 'Zika mosquitoes will come to the UK because of global warming - risking a 'large epidemic' of the incurable disease, MPs warn.' *Daily Mail*, 3 April 2019 https://www.dailymail.co.uk/news/article-6879895/Zika-mosquitoes-come-UK-risking-large-epidemic-incurable-disease-MPs-warn.html

Dobson, M. J. (1989) History of Malaria in England. *Journal of the Royal Society of Medicine Supplement,* 17, 82

Hogarth, A. M. (1928) *British Mosquitoes and How to Eliminate Them*, Hutchinson & Co

Semenza, J.C. and Suk, J.E. (2018) Vector-borne diseases and climate change: a European perspective, *FEMS Microbiology Letters*, 365, fnx244

Swain, M. (2012) 'Deadly mosquito found in the UK for first time since the 1940s'. *Daily Mirror,* 9 February 2012. https://www.mirror.co.uk/news/uk-news/deadly-mosquito-found-in-the-uk-for-first-678382

Vaux, A.G.C. and Medlock, J.M. (2015) Current status of invasive mosquito surveillance in the UK. *Parasites & Vectors* 8:351DOI 10.1186/s13071-015-0936-9

Melissa Graboyes (medical ethicist and historian, University of Oregon)

Remembering Malaria Elimination Failures in Zanzibar, 1920-2019: Arguments Against Mosquito Eradication

My contribution will be a historical and ethical discussion of why mosquito eradication is inappropriate by focusing on a case study of malaria elimination activities in Zanzibar, Tanzania over the past century. This contribution reconstructs the historical realities—failures—of malaria elimination on the island of Zanzibar and argues mosquito eradication should not be pursued due to the costs borne by local populations when failures occur, risks increase, and events such as rebound malaria take place. This case study raises the question of whether a narrow focus on trying to eradicate mosquitos unintentionally puts local communities at risk through loss of acquired immunity and increased likelihood of rebound malaria, and raises serious ethical questions about the nature of shared decision making, understandings of medium- and long-term risks of temporarily interrupting malaria, and the historical epidemiological of rebound malaria epidemics in Africa and globally. Evidence presented is primarily archival, and is part of a larger book project on the same topic.

Zanzibar has played a unique role in the history of malaria elimination attempts. Since the early 1900s, it has been used as a natural laboratory for malaria control and elimination measures by a host of international scientists attracted by the lure of malaria elimination in tropical Africa. Zanzibar has been idealized as an ideal site due its island ecology, small size, endemic levels of disease, small population, and relatively stable political climate. Initial efforts by the British protectorate government through the 1950s focused on mosquito elimination with environmental modifications, mapping and destroying mosquito breeding sites, and mass drug administration. The WHO's campaign in the 1950s focused on indoor residual spraying; the most recent interventions (largely funded by the U.S. President's Malaria Initiative) have emphasized insecticide treated bed nets, digital systems for tracking malaria cases, and spraying in hot spots. Current descriptions of malaria on Zanzibar describe the disease as "nearly eliminated" with prevalence of less than 1% on parts of the island and it is frequently used as an example of malaria conquered in tropical Africa. In reality, not a single program in Zanzibar over the past century has eliminated malaria. Malaria has been *nearly* eliminated multiple times, which is the same as saying it has *never* been eliminated.

Reviewing the past hundred years of malaria elimination efforts on Zanzibar, there are at least three clear conclusions. First, as Melinda Gates noted at the 2011 Gates Malaria Forum, "Zanzibar had an up-and-down history with malaria...the malaria burden in Zanzibar oscillated like a sine wave." Malaria rates on the island have plummeted and then rocketed back up at least three times, with prevalence rates in children ranging from 75% to under 5%. Second, despite multi-year interventions by international scientific agencies utilizing the best science and technology available, malaria transmission has never stopped on the island. Third, the failure to eliminate malaria led to the loss of acquired immunity among Zanzibaris, which allowed for two epidemics of rebound malaria to occur in the 1970s and 1980s.

Malaria is uniquely terrible in that there are risks that accrue to local people when the disease is effectively controlled for a number of years and then allowed to return unchecked. A temporarily successful control campaigns can create a more dangerous disease environment by stripping people of their hard-won acquired immunity and creating the conditions necessary for epidemics of rebound malaria. Acquired immunity is gained only by being exposed repeatedly and regularly to malaria infections and surviving. This means that in endemic spaces, mortality is typically confined to children and adults suffer primarily from morbidity, though this is not a water-tight pattern. Yet acquired immunity can be lost if a person is not regularly exposed to malaria. A control program or elimination attempt that reduces malaria prevalence to near zero or temporarily stops transmission

can create a situation ripe for rebound malaria—when malaria returns to communities where immunity has been lost and leads to extremely high mortality rates, even among adults.

The realities, challenges, and ethical dilemmas of rebound malaria are not new—scientists were familiar with the concept and debated it back to the 1940s. Epidemics of rebound malaria have been documented globally yet rarely get the attention they deserve. Seventy-five cases of resurgent malaria have been identified in 61 countries between the 1930s and 2000s and "almost all" of the cases were caused by the weakening of malaria control measures, most frequently "funding disruptions" (Cohen 2012). Focusing on a case study of malaria elimination attempts in a single place over time reveals with striking clarity what is at stake. When malaria elimination and control activities are temporarily successful—reducing or halting disease transmission—it can strip people of their hard-won acquired immunity and create a situation ripe for epidemics of rebound malaria. These epidemics typically have high mortality rates, even among adults. Thus, any attempt to eliminate malaria raises the specter of rebound malaria**.**

Zanzibar's history with malaria elimination failures and deadly rebound epidemics is not in doubt (though it's been almost entirely unreported). Archival evidence makes clear that WHO experts knew rebound malaria was a threat. Yet information about the risks of a rebound epidemic were not shared with Zanzibaris, no planning was done for the end, and measures were not taken to protect people from rebound epidemics. The rebound epidemic in Zanzibar, and the ethical questions that preceded and followed it, are not unique to this Indian Ocean island—they are the same question that vex malaria control activities globally, and more generally, can be said to vex any mosquito eradication attempt. If we're concerned about mosquitos because they are the vectors of diseases such as malaria, a focus on mosquitos is short sighted and does not sufficiently consider the risks that can arise when we fail to eradicate.

Citations:

Cohen, Justin M., et al. "Malaria Resurgence: a Systematic Review and Assessment of Its Causes." *Malaria Journal* 11, 1 (2012): 1-17.

Corbellini, G. "Acquired Immunity Against Malaria as a Tool for the Control of the Disease: The Strategy Proposed by the Malaria Commission of the League of Nations in 1933." *Parassitologia* 10 (December 10, 1998): 109–115.

Dobson, M.J., M. Malowany, and R.W. Snow. "Malaria Control in East Africa: The Kampala Conference and the Pare-Taveta Scheme: A Meeting of Common and High Ground." *Parissitologia* 42, no. 1-2 (2000): 149-166.

Graboyes, Melissa. "'The Malaria Imbroglio:' Ethics, Eradication, and Endings in Pare Taveta, East Africa, 1959-1960." *International Journal of African Historical Studies* 47, no. 3 (2014): 445-472.

Smith, David, Justin Cohen, Bruno Moonen, Andrew Tatem, Oliver Sabto, Abdullah Ali and Sultain Mugheiry. "Solving the Sisyphean Problem of Malaria in Zanzibar." *Science* 332, 6036 (2011):1384–85.

***NOTE: This is very much a draft of a position that I'm framing as "con" to mosquito eradication in response to your conference instructions. I'm not sure how I feel about making this argument publicly without since many of the malaria control/elimination groups I'm working with on this larger book project (on the history of malaria control/elimination efforts in East Africa) could be very offended by this type of position. I've written this in a far more polemical fashion than I normally would, and I'd appreciate feedback about how best to proceed.

NOT CURRENTLY USED, but these points could be integrated:

- Framing more broadly in relation to global helath projects? Global health projects bring with them a set of important ethical questions related to community involvement, risks, and acknowledging the true lifecycle of an intervention. The postcolonial realities of flows of money and expertise from the global north to the global south, the artificiality of funding cycles, the precarity of successes, and a refusal to acknowledge the afterlives of a project—these may appear as defining features of our contemporary, neoliberal, landscape. But these questions and patterns deserve to be historicized, and in fact have many historical precedents. These large concerns can also be condensed to a set of fairly simple questions: What happens in a place when an intervention ends? What kinds of risks might be acknowledged by scientists but not be well understood by community members? What does responsible planning for the end (or even failure) of a project, look like? These questions resonate across all areas global health where sustained funding is challenging and where changed disease ecosystems can increase local risk.

- More lit review/ positioning in literature? Drawing on recent work by anthropologists writing in Critical Global Health and Science and Technology Studies… ethical questions about decision making, flows of money and expertise from the global north to the global south, and how empowered and active communities on the receiving-end of these interventions would be. Could they refuse to participate in particular activities (i.e., release of genetically modified mosquitos, indoor residual spraying with particular insecticides, environmental modifications)? Building on the work of other historians, considering not just the scientific possibilities, but the effects on local communities and considering local understandings of eradication efforts, how they are viewed, valued, and whether a theoretical, academic, or scientific conversation also has moral implications.

- Discussion of control? If the goal is to reduce morbidity or mortality associated with malaria, perhaps a more realistic long-term plan is to focus on control, despite its unglamorous nature. We don't need to eradicate mosquitos for malaria to be reduced as a public health problem.

Frances Hawkes (medical entomologist, University of Greenwich)

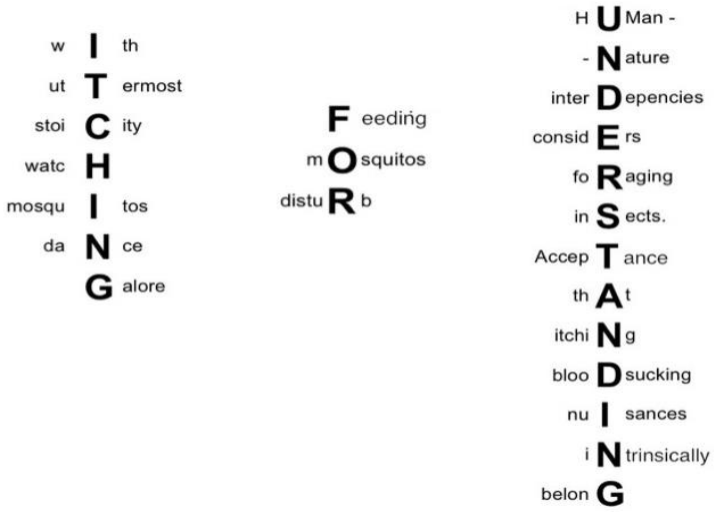
I'm a medical entomologist specializing in the behaviour and ecology of malaria mosquitoes of the genus *Anopheles*. I'm particularly interested in developing new or improved methods for mosquito control. My approach to this task is based on Sun Tzu's mantra from *The Art of War* – "Know your enemy and know yourself and you can win a hundred battles". I therefore study in detail the behavioural and ecological traits of mosquitoes, focusing on their host-location behaviour. In so doing one can see the mosquito's anatomy, behaviour and physiology as an awesome and even beautiful example of adaptation and evolution. But, for the purpose of public health entomology, it is also possible to identify particular behaviours that can then be incorporated into the design of 'bio-rational' control or surveillance devices and approaches, i.e. exploiting the mosquito's own biology to lure and/or kill them (Torr and Vale, 2015). Ultimately, my work takes me to malaria-endemic countries, and I have worked extensively in sub-Saharan Africa and Asia on these topics (Hawkes et al., 2017). I also work closely with a commercial partner (Biogents AG GmbH) to translate fundamental research into real-world products.

Outside of malaria-endemic countries, I work alongside Public Health England, the government department responsible for planning for and responding to public health issues arising from insects, particularly mosquitoes and ticks, in the UK. In collaboration with them and colleagues in social science, we conceived the wetlandLIFE project (www.wetlandlife.org), which is focused on building the evidence base to support wetland expansion for all its benefits, such as providing climate change mitigation and flood protection, biodiverse habitat and recreational space, without creating a potential nuisance from mosquitoes that may breed in wetlands. This project is as much about public perceptions of 'the mosquito menace' and the history and cultural representations of wetlands as 'disease-infested swamps' as it is about the ecology of British mosquitoes. I collaborate on this project with fellow Mosquitopia attendees Kerry Morrison and Helmut Lemke. I value public discourse on these issues and believe general education about the scientific method and uncertainty are important for ensuring the public understand the nuances of complexity and risk in general, and especially in vector-pathogen-host-environment interactions. I have a experience with the media, including feature documentaries (https://vimeo.com/133768254), TV, online news (https://www.bbc.co.uk/news/magazine-35408835) and magazines.

Kerry Morrison *(Socio-Environment Artist) and* ***Helmut Lemke*** *(Sound Artist) are members of the WetlandLIFE team in England. WetlandLife is a three-year (2016-19 / extended into 2020) interdisciplinary project funded by the AHRC, ESRC and NERC through the valuing Nature Programme in the UK.*

Itching for Understanding

Our project, ***ITCHING FOR UNDERSTANDING,*** is written as mesostic poem, which reads: "with uttermost stoicity watch mosquitos dance galore / feeding mosquitos disturb / human – nature interdependencies consider foraging insects Acceptance that itching bloodsucking nuisances intrinsically belong". In this poem our philosophy, our aim and our approach are shared.



As artists, we are irresistibly drawn to maligned species and landscapes and seek to uncover aesthetic and ecological qualities where they are neglected or vilified by some and where others may see ugliness, nuisance, or negative impacts. Previous work exploring these hidden qualities and benefits include: polluted watercourses (Forever Flowing), seagulls (Give and Take), bird droppings (Bird Sheet Music), insects (Dishing the Dirt), brownfields (Anyone's Garden), and the 'Surplus value of Sound'. Himalayan Balsam, Dandelions, moss and 'weeds' in general have also been subjects of our artistic research..

Working within the Valuing Nature Programme we seek to reposition the vilified mosquito and highlight its role and benefits within the delicate web of interdependence in wetland ecosystems.

In our contribution to Mosquitopia we will tell of the journey of two artists to a better understand the mosquito: to find out about the purpose and the aesthetic qualities of an creature that is otherwise reduced to being a nuisance or a dangerous health threat.

We will report about our presence in the Wetlands at Alkborough Flats in North-Lincolnshire and Priory and Millennium Parks in Bedfordshire. We will also explain our approaches to sharing our thought processes with wetland managers and wider audiences including farmers and visitors, and members of nearby communities who may not be currently engaging with the wetlands on their doorsteps.

Alex Nading (anthropologist, Brown University)

Eradication against Ambivalence

For the "Mosquitopia" conference, I will be asking my fellow participants to reflect on the social and political possibilities that are foreclosed by the project of eradication.

Looking across a variety of mosquito-borne disease control projects, I want to suggest that the public health value of mosquito control technologies comes from the ambivalence they produce in the humans who use them or interact with them. Through my anthropological fieldwork among front-line mosquito control workers in Central America, who use larvicides to control Aedes aegypti, I learned that the call to kill mosquitoes can—under certain circumstances—induce an appreciation of the complexity of the worlds shared and shaped by people, insects, and microbes. Indeed, under certain circumstances, tracking and killing mosquitoes can be pleasurable. That pleasure can translate into a sustained commitment to public health. Here, I refer to "public health" in its broadest sense: not only management of specific diseases (e.g. arboviruses or malaria) but also improved infrastructure, reduction in crime, and access to food and water, among other things.

My findings indicate that this commitment to public health takes hold because the effort to control mosquitoes is understood to be partial, halting, and inherently incomplete. All current approaches to Aedes aegypti control (from the traditional larviciding I studied, to genetic modification, to *Wolbachia* infection) are similarly imperfect. Evidence shows that when it comes to implementation, the common thread across these approaches is ambivalence.

Eradication fails as a public health measure precisely because it forecloses the possibility of ambivalence. Drawing on anthropological critiques of both ambitious mega-projects and more modest health interventions, I want to argue against eradication not because I think it is categorically unethical or ecologically catastrophic, but because it artificially seeks to insulate public health from the messy realities of sociality and politics.

References:

Carr, E. Summerson. 2015. Occupation Bedbug: Or, the Urgency and Agency of Professional Pragmatism. *Cultural Anthropology* 30(2): 257-285.

Redfield, P. 2017. On Band-Aids and Magic Bullets. *Limn* 9, https://limn.it/articles/on-band-aids-and-magic-bullets/

Kelly, Ann and Javier Lezaun. 2014. Urban mosquitoes, situational publics, and the pursuit of interspecies separation in Dar es Salaam. *American Ethnologist*, 41: 368-383.

Ramya Rajagopalan (bioethicist, UC San Diego)

Gene drives, designer mosquitoes, and the networked "nature" of interspecies relationships

As vector-borne diseases (VBDs) ravage public health systems around the world despite decades of efforts to combat them, some researchers have begun to develop CRISPR-Cas9 precision "gene drives," capable of spreading genes for parasite immunity or sterility through mosquito breeding populations. The potential to repopulate local environments with "gene drive" mosquitoes inspires a range of visions for the future of mosquito-human relationships, from the targeted extinction of the few mosquito species that spread VBDs, to the possibility of radically redesigning mosquito vectors to halt parasite and VBD transmission altogether. In the latter case, new classes of genetically modified mosquitoes might co-exist peacefully with human societies without devastating them with disease. But what costs might humans, mosquitoes, parasites, and local and global ecologies incur in the process of re-engineering mosquitoes to benefit humans? Drawing on themes from science and technology studies that seek to blur the categorical binaries between nature and society, this paper will explore several ways that "designer mosquitoes" might fundamentally reshape interspecies relations between humans and the insect pests that plague them. These reworkings could nevertheless present new ethical binds, as ensuring the future health of humans might endanger the health of the species webs they inhabit.

Luísa Reis-Castro (anthropologist of science, MIT)

Placing Mosquitoes: the *Aedes aegypti* in Brazil

Mosquito: the "most dangerous animal on Earth," human's "deadliest predator." This insect is often described as the quintessential illustration of gene-editing technologies that have the potential to eliminate the unwanted. Mosquitoes are usually presented as the number one enemy of humankind, a globally hated pest: the most killable of all critters.

This piece proposes to interrogate and destabilize the general, amorphous categorization of *mosquitoes*. In order to illustrate the mosquito's multiplicity, one could point to the various species within the category, creatures that populate diverse ecosystems across the world—and of which only a small fraction can transmit harmful pathogens. However, here I focus on one particular species: the *Aedes aegypti*, the infamous vector of viruses, including Zika, dengue, chikungunya, and (urban) yellow fever. If what brings us together in this Symposium is a call to debate "whether, how, and if humans can co-exist with mosquitoes," my position statement argues that it matters which humans and which mosquitoes we have in mind. In other words, if we are to inquire about the "Place of Pests in a Healthy World," I ask: who considers mosquitoes as pests, and, most importantly, why? By zeroing in on only one species, I show how the *A. aegypti* has been perceived and tackled in varying ways, arguing it matters how these insects are framed, and by whom, and how these different mosquito understandings shape the historical and social conditions of efforts to control both these insects and the pathogens they can transmit. I examine three moments in Brazilian history in which the *A. aegypti* was particularly notorious as the vector for viral diseases: yellow fever, dengue, and Zika.[9] Secondly, I analyze contemporaneous contexts in which the *A. aegypti* might not be considered a pest, namely in non-urban spaces and in campaigns using mosquitoes themselves to control the pathogens they can transmit. I conclude by pointing out the impossibility of having a generalizable, universal approach to the *place* of mosquitoes. Instead, I highlight the importance of considering particular cases, and assert the need for those planning and implementing projects to control mosquito-borne diseases to examine and take into account the histories and specificities of the *places* these mosquitoes inhabit.

If climate change is expanding the geographical spread of some insects, ushering a new mosquito epoch in certain parts of the world, these buzzing, biting critters have for long been a question for the humans living in warmer regions of the planet. In Brazil, for example, the *A. aegypti* has had a historical trajectory spanning more than one hundred years. This species probably came to the Americas from Africa during the many decades of colonialism and slave trafficking, in the ships that moved goods and people around the Atlantic (Sedrez 2004). Nevertheless, it was only at the beginning of the twentieth century, once researchers had established that the mosquito was the vector for (urban) yellow fever, that the insect became the target of public health campaigns (Delaporte 1991; Benchimol 2001; Magalhães 2016). During the first decades of the twentieth century, medical and political elites in Brazil called for the treatment and prevention of diseases as a fundamental step towards overcoming the country's "backwardness" and as a means to "modernize" the nation (Hochman 2016; Löwy 2006). This plan took its lead from public health and scientific narratives that claimed the environment could influence the moral and physical makeup of its citizens. Hence, controlling diseases like yellow fever could "civilize," or "improve," the country's population—a project historian of science Nancy Leys

[9] The study of the *A. aegypti*'s one hundred year old historical trajectory in Brazil is part of a collaborative project with historian Gabriel Lopes. In a forthcoming (October 2019) book chapter, we examine how, in spite of there being a continuity in dominant designations of the mosquito as the "epidemic villain," the epidemiological and political meanings of these different virus-mosquito-human interactions significantly change over the span of time.

Stepan (1991) has defined as "soft eugenics," the idea that race could be "ameliorated" through social and environmental transformation. In addition, some politicians and public health officials also saw controlling yellow fever as pivotal for enforcing racist "whitening" policies that promoted the immigration of (white) Europeans to Brazil, since the new immigrants/settlers were considered to be particularly susceptible to the virus (Nascimento 1978; Chalhoub 1993; Schwarcz 1999; Santos 2002). In the 1980s, the *A. aegypti* once again became the target of public health campaigns, this time for its role in transmitting the dengue virus. The mosquito, which had been eliminated from Brazil in the 1950s, had crept back into the country during the years of dictatorship. The military government, which ruled Brazil from 1964 to 1985, had dismissed reports of the mosquito's return, discrediting and persecuting the scientist who sounded the alarm (Lopes and Reis Castro 2019). With the *A. aegypti* present throughout the sprawling cities, the dengue virus quickly spread. Those affected by the disease, in particular residents of lower-income neighborhoods in the outskirts of Rio de Janeiro, protested the outbreaks, which they saw as a result of the government's historical disregard for their well-being, and especially their health and sanitary conditions. These demonstrations occurred during the "redemocratization" process, with protesters demanding a broader understanding of health and healthcare access as a state assured right (Pires-Alves, Paiva, and Lima 2018). These ideas would become part of a national debate, and healthcare was guaranteed as a constitutional right with the creation of the 1988 *Sistema Único de Saúde* (SUS), the national, public, universal health system (Jerome 2015; Paim et al. 2011).

Despite policies and strategies to control the *A. aegypti*, the mosquito continued to proliferate in Brazilian cities, transmitting the dengue virus and, after 2014, the chikungunya virus. Outbreaks of these diseases became a recurring, almost expected urban public health issue in the country. However, in late 2015-early 2016, the mosquito regained notoriety for being the vector for a different pathogen: Zika. The virus was linked to fetal malformation and congenital issues in newborns, most notably microcephaly. Exposure to the *A. aegypti* mosquito and, consequently, to the virus was discussed within a tension between two poles: while some argued that anyone could be bitten, others pointed out that certain conditions, in particular poverty, caused some to be more vulnerable than others (Lesshafft 2016; cf. Castro, Khawja, and Johnston 2010; Valle, Pimenta, and Cunha 2015; Segata 2016). The somatic effects of the Zika virus and the recommendation for "women to postpone pregnancy" during the epidemic brought forward debates about reproductive justice in Brazil. Abortion is a crime in the country, except in cases of rape, risk to mother's life, and anencephalic fetuses (Medeiros Santos 2017). However, those who can afford it pay for a clandestine but medically safe procedures and are rarely prosecuted for it. Zika was mobilized by both feminists and conservative groups: the first, argued for the need to decriminalize/legalize abortion as a social justice issue since poor, mostly black and brown, women were unequally harmed by both the procedure's illegality and the impacts of Zika, while the latter argued for the need to further hamper access to abortion since it could be used as an "eugenic tool" against disable children, like those with Congenital Zika Syndrome (Lira, Meira, and Campos 2018). Furthermore, the Zika epidemic happened during a time of intense political polarization in the country, intensified by the coup/ impeachment of the President Dilma Rousseff. While still in power, the Rousseff administration had tried to use the "fight against the mosquito" to unite the country against a common "enemy" and to show a determined, combative government (Nunes and Pimenta 2016); however, Rousseff's opposition mobilized the epidemic and broader deficiencies of the Brazilian public health system as part of a larger argument about the state's managerial incompetence.

The study of these three historical moments demonstrate how the same mosquito, the *A. aegypti*, has been considered a pest for different reasons: as hindering "civilizing" and "whitening" endeavors; as reinforcing social inequalities and uncovering governmental disregard; and as escalating reproductive injustice and testing state's efficacy. These different mosquito understandings shaped how the priorities of disease control were defined and how the endeavors to tackle illness by controlling the mosquito were perceived. Nevertheless, in certain situations the *A. aegypti* may not even be considered a pest. For example, Túllio Maia's (2018) ethnographic research has described how, for

the *sertanejos*--those living the non-urban areas of the Brazilian northeast countryside--insects like the *A. aegypti* did not "cause disease." These *sertanejos* ascribed diseases like Zika as being transmitted by mosquitoes only in cities, with their dirt, trash and sewage. Away from the urban context, mosquito bites were not a vehicle for pathogenic viruses, but rather understood as part of the insect's struggle to survive the arduous environment in the *sertão*, in the same way that the *sertanejos,* and other inhabitants, were also continuously striving to survive.

Finally, as part of my dissertation research examining new technologies for vector control in Brazil, I conducted fieldwork with a group releasing modified *A. aegypti* throughout the city of Rio de Janeiro. This global health group, the World Mosquito Program (WMP), is one among different projects across the world now trying to use the mosquitoes themselves to control the pathogens they can transmit (Reis Castro 2012; Nading 2014b; Beisel and Ganle 2019). WMP releases *A. aegypti* infected with the bacterium *Wolbachia*, a microbe that can inhibit the insect's ability to transmit pathogens, expecting that these mosquitoes will mate with the so-called "wild ones" and pass on the bacteria to the next generation. In other words, the goal is to turn mosquitoes from vector into non-vector. Or as my interlocutors put it, there is thus a shift: the "problem to be controlled" is no longer the insect but the virus and, by becoming non-vectors, the *A. aegypti* infected with *Wolbachia* are transformed into "allies" in efforts to tackle diseases. WMP is releasing these mosquitoes in Rio de Janeiro, where the municipality declared bankruptcy and where, during my fieldwork, public health agents who collaborated with the WMP were on strike for not receiving their salaries. Furthermore, the city has dealt in the last years with extremely violent conflicts, where shootings and gunfights between drug dealers, *milicianos* (paramilitary, mafia-style groups), and police/military forces happen regularly and often with fatal outcomes, especially in low-income, black communities. Rio's public financial deficiencies and widespread violence not only complicated logistics for WMP, but it also brought forward questions about the priority of releasing *Wolbachia*-infected *A. aegypti*. Or as someone put it during a WMP "public engagement" activity in one of these low-income neighborhoods, "Dengue might kill, but what really kills here are 'stray bullets,' which always end up somehow finding their way into our black bodies."

"Placing" mosquitoes—that is, putting these insects in particular places, positions, and contexts—demonstrates how even one species can be embroiled in different narratives, debates, struggles, and agendas, and how, concomitantly, these different *A. aegypti* framings shape multispecies perceptions and interactions and, more specifically, vector control efforts (see also Slosek 1986). To understand the *place* of mosquitoes, I draw from anthropologists, geographers, and other social scientists who have described how "place" is not bounded, static nor singular, but a social, political, and historical process always changing and in-the-making (Pred 1984; Zukin 1993; McKittrick and Woods 2007; Low 2009; Messeri 2016; Hinkson 2017). The presence of the *A. aegypti* and mosquito-borne diseases in Brazil, or in any part of the world, cannot be dissociated from the histories that shape our environments and societies. Anthropologist Alex Nading (2014a) defines these connections in terms of the "politics of entanglement," the complex knots of people, mosquitoes, urban environment, and social, cultural, and medical practices. By describing these various understandings of the *A. aegypti*, a species notorious for its role in transmitting viral diseases, I showed how it is important to examine the ways in which places make mosquitoes and mosquitoes make places. I conclude by arguing that any project that might consider eliminating mosquitoes, or any other effort to address mosquito-borne diseases, should reflect on who is implementing the project, where and how is it being developed, who are those affected by it, and what are the motivations/support for choosing this project…. In other words, place matters when considering the place of mosquitoes.

References:

Beisel, Uli, and John Kuumuori Ganle. 2019. “Commentary - The Release of Genetically Engineered Mosquitoes in Burkina Faso: Bioeconomy of Science, Public Engagement and Trust in Medicine.” *African Studies Reviw*, 164–73.

Benchimol, Jaime Larry. 2001. *Febre Amarela: A Doença e a Vacina, Uma História Inacabada*. Rio de Janeiro: Editora Fiocruz.

Castro, Arrachu, Yasmin Khawja, and James Johnston. 2010. “Social Inequalities and Dengue Transmission in Latin America.” In *Plagues and Epidemics: Infected Spaces Past and Present*, edited by Ann Herring and Alan Swedlund, 231–249. New York: Berg.

Chalhoub, Sidney. 1993. “The Politics of Disease Control: Yellow Fever and Race in Nineteenth Century Rio de Janeiro.” *Journal of Latin American Studies* 25 (03): 441–63.

Delaporte, François. 1991. *The History of Yellow Fever: An Essay on the Birth of Tropical Medicine*. Translated by Arthur Goldhammer. *1989*. Cambridge and London: MIT Press.

Hinkson, Melinda. 2017. “Precarious Placemaking.” *Annual Review of Anthropology* 46: 49–64.

Hochman, Gilberto. 2016. *The Sanitation of Brazil: Nation, State, and Public Health, 1889-1930*. Urbana: University of Illinois Press.

Jerome, Jessica Scott. 2015. *A Right to Health : Medicine, Marginality, and Health Care Reform in Northeastern Brazil*. Austin: University of Texas Press.

Lesshafft, Hannah. 2016. “Is Zika a Disease of Poverty?” Somatosphere: Science, Medicine, and Anthropology. 2016. http://somatosphere.net/forumpost/is-zika-a-disease-of-poverty.

Lira, Luciana Campelo, Fernanda de Souza Meira, and Roberta Bivar C. Campos. 2018. “Tensões e (Re)Elaborações Sobre Gênero e Deficiência No Debate Sobre Aborto: Reflexões Etnográficas No Contexto Da Síndrome Congênita Do Zika Vírus.” In *Reunião Brasileira de Antropologia*. Brasília.

Lopes, Gabriel, and Luísa Reis Castro. 2019. “A Vector in the (Re)Making: A History of Aedes Aegypti as Mosquitoes That Transmit Diseases in Brazil.” In *Framing Animals as Epidemic Villains*, edited by Christos Lynteris. London: Palgrave Macmillan.

Low, Setha M. 2009. “Towards an Anthropological Theory of Space and Place.” *Semiotica* 175 (1/4): 21–37.

Löwy, Ilana. 2006. *Vírus, Mosquitos e Modernidade: A Febre Amarela No Brasil Entre Ciência e Política*. Translated by Irene Ernest Dias. *[2001]*. Rio de Janeiro: Editora Fiocruz.

Magalhães, Rodrigo Cesar da Silva. 2016. *A Erradicação Do Aedes Aegypti Febre Amarela, Fred Soper e Saúde Pública Nas Américas (1918-1968)*. *História e Saúde Collection*. Rio de Janeiro: Editora Fiocruz.

Maia, Túllio Dias da Silva. 2018. “Cada Um Com Sua Luta : Uma Etnografia Da Relação Entre Sertanejos e Mosquitos No Alto Sertão Sergipano.” Universidade Federal de São Carlos.

McKittrick, Katherine, and Clyde Woods, eds. 2007. *Black Geographies and the Politics of Place*. Toronto: Between the Lines.

Medeiros Santos, Flávia. 2017. “"De Criminosa a Vítima: Abortos, Polícia e Direitos Humanos Na Região Metropolitana Do Rio de Janeiro.” In *Antropologia e Direitos Humanos 7*, edited by Lucía Eilbaum, Patrice Schuch, and Gisele Fonseca Chagas. Rio de Janeiro: Associação Brasileira de Antropologia.

Messeri, Lisa. 2016. *Placing Outer Space: An Earthly Ethnography of Other Worlds.* Durham: Duke University Press.

Nading, Alex M. 2014a. *Mosquito Trails Ecology, Health, and the Politics of Entanglement*. Berkeley: University of California Press.

———. 2014b. “The Lively Ethics of Global Health GMOs: The Case of the Oxitec Mosquito.” *BioSocieties* 10 (1): 24–47.

Nascimento, Abdias do. 1978. *O Genocídio Do Negro Brasileiro: Processo de Um Racismo Mascarado*. Rio de Janeiro: Editora Paz e Terra.

Nunes, João, and Denise Nacif Pimenta. 2016. “A Epidemia de Zika e Os Limites Da Saúde Global.” *Lua Nova* 98: 21–46.

Paim, Jairnilson, Claudia Travassos, Celia Almeida, Ligia Bahia, and James MacInko. 2011. “The Brazilian Health System: History, Advances, and Challenges.” *The Lancet* 377 (9779): 1778–97.
Pires-Alves, Fernando Antônio, Carlos Henrique Assunção Paiva, and Nísia Trindade Lima. 2018. “Na Baixada Fluminense, à Sombra Da ‘Esfinge Do Rio’: Lutas Populares e Políticas de Saúde Na Alvorada Do SUS.” *Ciência & Saúde Coletiva* 23 (6): 1849–58.
Pred, Allan. 1984. “Place as Historically Contingent Process: Structuration and the Time-Geography of Becoming Places.” *Annals of the Association of American Geographers* 74 (2): 279–97.
Reis Castro, Luísa. 2012. “Genetically Modified Insects as a Public Health Tool : Discussing the Different Bio-Objectification within Genetic Strategies.” *Croatian Medical Journal* 53: 635–38.
Santos, Sales Augusto dos. 2002. “Historical Roots of the " Whitening " of Brazil.” *Latin American Perspectives* 29 (1): 61–82.
Schwarcz, Lilia Moritz. 1999. *The Spectacle of the Races: Scientists, Institutions, and the Race Question in Brazil, 1870-1930*. New York: Hill and Wang.
Sedrez, Lise Fernanda. 2004. “‘The Bay of All Beauties’: State and Environment in Guanabara Bay, Rio de Janeiro, Brazil, 1875-1975.” PhD Dissertation in History - Standford University.
Segata, Jean. 2016. “A Doença Socialista e o Mosquito Dos Pobres.” *Iluminuras* 17 (42): 372–89.
Slosek, Jean. 1986. “Aedes Aegypti Mosquitoes in the Americas: A Review of Their Interactions with the Human Population.” *Social Science & Medicine* 23 (3): 249–57.
Stepan, Nancy Leys. 1991. *The Hour of Eugenics : Race, Gender, and Nation in Latin America*. Ithaca: Cornell University.
Valle, Denise, Denise Nacif Pimenta, and Rivaldo Venâncio da Cunha. 2015. *Dengue: Teorias e Práticas*. Rio de Janeiro: Ed. Fiocruz.
Zukin, Sharon. 1993. *Landscapes of Power: From Detroit to Disney World*. Berkeley: University of California Press.

Nancy Leys Stepans (medical historian, Columbia University)

We are asked to think about the question: "Even if we *could* rid ourselves of mosquitoes, would we still want to?"

This does an excellent job of focusing our minds on critical matters of ecology and ethics, matters which are admirably and comprehensively set out by Marcus Hall and Dan Tamir in their position paper.

But as a medical historian who has engaged with the messy details of past efforts to eradicate mosquito species, I am finding it difficult to abstract the "could we?" part of the story from the "should we?; difficult, that is, to disentangle or bracket off the eradication process, and take the extinction of the mosquito as a given, because embedded in the "could we?" are already many "would/should we?" issues. How is extermination of a given mosquito species to be done, and at what costs? What exact methods do we propose? Are there ecological/ethical issues associated with the methods we use? What does "getting rid" of a mosquito imply – local elimination, or world-wide reduction to zero?

As a critic of eradicationism as a philosophy of public health, I take the position that the complete eradication of an entire mosquito species is probably not feasible; is possibly not desirable, ecologically and/or ethically; and above all, *is not necessary from a public health point of view*.

Not Feasible?

In order to highlight the "could we/should we" nexus I look briefly at four campaigns that were each designed explicitly to eradicate a specific mosquito species. All four were led by the arch-eradicationist of the 20th century, Fred Soper, a Rockefeller Foundation official before World War II, then Director of the Pan American Health Organization after. The campaigns may well represent the best evidence we have of such efforts.

In two campaigns, Soper managed to eradicate the malaria-transmitting *Anopheles gambiae* from specific regions, first in the northeast of Brazil in 1938-1941, then in Upper Egypt in 1944-1945, based on anti-larval and home spraying of (pre-DDT) chemicals. This was a considerable achievement, and helped reduce epidemic malaria. But the gambiae species was a recent arrival in both countries, was not well established in either, and so not fully integrated into the local ecology. It was a noteworthy regional eradication, a good example of stopping a harmful invasion of a dangerous species, but not a true test of the possibility of eradicating an indigenous or well-established disease-transmitting mosquito over a large area, let alone the world.

The campaign (1946-1950) to eradicate the malaria vector, *Anopheles labranchiae,* on the island of Sardinia was such a test – an experiment organized by Soper as a deliberate effort to rid the island of a well-established mosquito completely, based on the spraying of thousands of tons of the new wartime discovery, the insecticide DDT, from the air and in homes. At the end of 5 years malaria had disappeared, and did not re-appear when spraying stopped – seemingly a very satisfactory public health result. But the mosquito itself survived, if only in severely reduced numbers. Thought of as a test of mosquito eradication, it proved that completely eradicating a well-established mosquito was very difficult, if not impossible, at least not with DDT, and not in the kind of terrain where the mosquito was found.

The campaign to eradicate the urban vector of yellow fever, *Aedes aegypti*, from the continental Americas was in point of time the first of Soper's mosquito extermination efforts to be launched, is the least commented upon, yet in several respects is perhaps the most interesting of all Soper's campaigns; it was the source of Soper's original belief in the possibilities of species eradication, and

the most sustained effort he made to achieve that end, lasting from the mid-1930s to the late 1960s and beyond. Convinced that relying on the new vaccine 17D (available after 1937) would not be enough to control urban yellow fever, he pursued mosquito eradication through the careful larviciding of breeding sites and house spraying, initially using Paris Green and pyrethrum respectively; the campaign was taken up across the Americas after World War II and, relying on DDT and similar insecticides, was pursued for years. Through persistent effort, *A. aegypti* and urban yellow fever virtually disappeared and remained absent for decades.

But continent-wide elimination of the mosquito was never maintained, with insecticide-resistance becoming an increasing problem, re-invasion of the mosquito into cleared areas, and growing resistance by countries to directing so much effort against *A. aegypti* when mosquito and yellow fever indices were so low as to be virtually non-existent. Eradication was eventually abandoned, and even efforts at vector suppression cut back, with the inevitable outcome -- *A. aegypti* returned everywhere, with the eventual consequences we know:- dengue epidemics erupted, and now Zika.

The campaigns showed mosquitoes, and insects more generally, are arguably among the most resilient and successful of animal species; they resist their extermination. Already in the DDT era, disease eradication had replaced species eradication as the goal in international public health; but disease eradication also proved elusive, with only one success, smallpox (achieved by vaccination).

Not Desirable?

Soper's mosquito eradication efforts were in effect "pre-" or even "anti" ecological. He famously said he regretted the term "ecology" had ever been invented. Soper knew very little about the *Anopheles gambiae* species when he tackled it, treating it as though it were the same, in relation to eradication methods, as the completely different mosquito, *Aedes aegypti*. He knew much more about the behaviour of *Aedes aegypti*, but the question of the possible ecological effects of removing a species completely from most of the Americas does not seem to have been raised; I have a sense there were no such effects (but *Aedes aegypti* did not, of course, disappear entirely; this remains a question to be answered as new technologies are being tested against *A. aegypti* and *Anopheles gambiae*).

Ethically, there were many questions surrounding these species eradication efforts:-- the risks of Paris Green and DDT, to humans, to animals, to the environment more generally, were not fully addressed or recognized; consent to the inspection and spraying with chemicals of people's homes was not asked for; instead mandatory inspections were imposed on households and fines used for non-compliance. Finally, the over-reliance on a biomedical model of public health meant there was a neglect of alternative or additional social methods of disease control (such as ensuring piped water, screened windows, and regular rubbish collections in communities at high risk of mosquito-borne diseases).

Not Necessary? Control versus Eradication

Turning to the present, post-Zika, we confront again the question of mosquito eradication. *If we could, should we?*

Sending in 200,000 soldiers to help battle Zika, as happened in Brazil in 2016 in response to the epidemic, is more an exercise of public relations than a thought-out sustainable project of public health. New tools are sought, most of them "high tech" and still at the experimental stage. Will these new bio-engineering methods escape the "could we/should we" entanglement? Are the effects on the ecological balance known fully? Are their risks understood? Uncertainty, unforeseen effects, and incomplete knowledge seem to be ineluctably part of any eradication programme.

Is the language of eradication, indeed, useful? Or necessary? Eradication sets a very demanding goal, a high bar, requiring a high degree of commitment and costs; it risks creating disappointment and abandonment of efforts when complete eradication proves elusive.

It is worth remembering that originally, the anti-mosquito vector programmes aimed not at complete eradication, but at reducing the targeted mosquito indices to a low level, below which the transmission of the pathogen was found not to be sustainable. In the case of yellow fever, reducing the incidence of *Ae* mosquito larvae to 5% or less of houses in a targeted population stopped yellow fever transmission in Havana, New Orleans, and Rio de Janeiro in the first decades of the twentieth century.

The lessons from these histories is that mosquito control is the best we can hope for. The goal of mosquito reduction, using multiple new and old methods, along with much more participatory models of public health than in the past, seems to me to combine the positive aspects of Soper's determination to deal with the mosquito as a major factor in disease transmission, with René Dubos's ecological view that takes into account the dynamic and continuous processes by which insects, pathogens, and humans interact, adapt and co-evolve. It achieves a better balance between human health and environmental health as we battle against climate change (potentially increasing the spread of mosquito-borne infections), and the loss of species. Control methods, old and new, also raise difficult ethical and ecological questions; but aiming for the reduction of mosquito populations is less demanding and less distorting of public health.

Willem Takken (disease ecologist, University of Wageningen)

Sustainable, non-polluting methods of mosquito control for prevention of vector-borne diseases

Mosquitoes belong to a group of organisms that affect human health and mosquito-borne disease leads to an estimated 750 thousand deaths per year (Global Vector Control Response, WHO 2017). The role of insects in the transmission of disease was discovered in the last two decades of the 19th century [ref], notably with the role of *Culex quinquefasciatus* as vector of filariasis parasites, *Aedes aegypti* as vector of the yellow fever virus and anopheline mosquitoes as vectors of malaria parasites. The landmark work by Sir Ronald Ross on the transmission of malaria parasites by mosquitoes initiated an era of disease control aimed at the destruction or elimination of the mosquito vectors.

Early in the 20th Century, Gorgas organized the control of *Aedes* and *Anopheles* mosquitoes for control of yellow fever and malaria, respectively, in the Panama isthmus, thus enabling the completion of the Panama canal. Around the same time, Watson and Swellengrebel developed methods for mosquito larval control by species sanitation in India, Malaysia and Indonesia (Wilson et al. PNTD In Press). These control programmes were successful due to the understanding of the biology and ecology of the vectors. By modification or removal of larval habitats, the mosquitoes were prevented from ovipositing which led to their extinction. Species sanitation, mostly by drainage of wetlands, has been widely used for the elimination of malaria from North America [e.g. Tennessee Valley scheme].

Although it was realized early on that chemical insecticides could contribute to vector control, until the 1940s these were mostly based on pyrethrum and Parish green. Pyrethrum, a natural product from *Chrysanthemum* species, has a very short life time, while Parish green was highly toxic but dangerous to human health. Only after the discovery of DDT in 1939, and its subsequent widespread distribution at the end of the 2nd World War, became insecticides the mainstream of vector control. This was so effective, that the environmental methods pioneered in Panama and SE Asia were largely forgotten. Within a very short time, malaria was eliminated from Europe, Japan and Australia, and then followed by Asian Russia as well. The World Health Organization launched a global malaria eradication programme (GMEP) in 1955 based on the successes with these chemical insecticides as well as the availability of effective and cheap antimalaria drugs.

Although the GMEP was initially successful, by the late nineteen sixtees it ran aground due to steeply rising costs and the realization that insecticide resistance was widespread. In 1969 the GMEP was abandoned, and malaria control could rely mostly on diagnosis and drug treatment. Surprisingly, few countries employed the previously successful environmental management programmes.

Synthetic pyrethroids, developed in the nineteen seventies, proved very effective in killing mosquitoes when integrated in bed nets. Indeed, studies in West Africa demonstrated effective malaria control using insecticide-treated bed nets (ITNs), and in 2000 WHO recommended its use as the method of choice for malaria control, launching the Roll Back Malaria programme. Coupled with new insecticides for indoor residual spraying, the malaria eradication campaign was renewed in 2007. This programme was initially highly successful: by 2015 a global reduction of 50% in malaria mortalilty could be reported. Seventy % of this reduction could be attributed to ITNs, and a further 10% to IRS. However, at the same time it was reported that malaria mosquitoes were developing resistance against pyrethroids as well as insecticides used for IRS, threatening further progress.

Could this resistance disaster have been avoided? Along with the development of ITNs alternative tools were under study. Studies with biological control of malaria mosquitoes proved very successful: mosquito larvae could be killed with *Bacillus thuringiensis israelensis*, and larval and adult mosquitoes could be killed with entomopathogenic fungi *Metarhizium anisopliae* and *Beauveria*

bassiana. Studies with these tools remained limited, however, as these required large-scale epidemiological studies before they could be considered as alternatives to ITNs or IRS. A different approach was the development of odour-baited traps to lure mosquitoes into traps baited with synthetic human scent. An epidemiological field study in Kenya demonstrated the effectiveness of this method, leading to more than 30% reduction of malaria prevalence, and strong reductions in mosquito densities. This odour-based approach can be further advanced as a push-pull system, where spatial repellents and attractants are strategically employed to lure mosquitoes into traps. In West Africa studies are under way with eave traps, luring mosquitoes into the trap with natural human scent. Next to these tools that exploit the biology of the mosquito and its natural environment, the improvement of houses has also been shown to lead to less malaria: in poverty stricken rural areas houses have many gaps that serve as mosquito entry points. By closing such gaps, through house improvement, it was shown that improved houses led to less disease. Drainage of potential breeding sites is still an excellent option where applicable, especially in urban settings.

These examples demonstrate that for the control of vector-borne disease (VBD) effective tools are already present that can remove our reliance on chemical insecticides. These tools have the huge advantage that they do no induce resistance. The biological control agents act on several toxic genes for which it is difficult to develop resistance all at once. The trapping methods, as well as house improvement, are unlikely to lead to selective behaviour that affects chemical control so readily.

In the history of VBD control the elimination of mosquitoes has rarely been considered. On the one hand, most control was local, where mosquitoes in adjacent areas were not affected. Also, in many programmes mosquito populations were reduced to such low levels that the probability of a parasite or pathogen transmission became zero or very small. To-date, there is not one geographic region where indigenous mosquito species have gone extinct due to a deliberate action of a disease control programme. During the global malaria and yellow fever eradication campaigns of the 1950s mosquito populations were locally strongly reduced in many countries. In one case: South America, *Aedes aegypti* became extinct due to designated control programmes. This species was introduced in the Americas with the slave trade of the 1600s, and thrived well. During a designated control programme, mostly insecticide-based, the species was eliminated from South America in the 1960s. However, by the late 1980s the species re-invaded South America once again, and has since become re-established throughout that continent.

Mosquito populations show a strong resilience to changes in population densities that threatens their survival. At present it is reported that in much of tropical Africa the malaria vector *Anopheles gambiae* has been much reduced in density since the area-wide distribution of ITNs and IRS. However, a direct causal relationship has not been found. It is possible that economic development processes in Africa are detrimental to this species. The relatively recent invasion of *Aedes albopictus*, a vector of several arboviral diseases, of Australia, Africa, Europe and the America's from its origin in SE Asia, is an example of how some species benefit from global developments.

Mosquitoes, including those that are known as vectors of infectious disease, have been around on the planet longer than humankind. This group of insects, which depends on vertebrate blood, has shown a remarkable ease in adaption to changes in its environment, as shown by its highly opportunistic behaviour in selection of aquatic sites. Of the >3000 known mosquito species, few are so selective that they could possibly be eliminated from specific areas. Such an approach might be undesirable in terms of biodiversity, but it is generally thought that one of the other mosquito species would occupy a niche once it becomes available. The extraordinarily capacity to adapt to its environment, and a high reproductive rate, should be considered strong traits in organisms that are by many considered as pests. In the opinion of this author, however, we should respect such traits in mosquitoes and develop tools that prevent us from being bitten, and not expect that we can exterminate them.

Kenneth Vernick (insect vector geneticist, Institute Pasteur, Paris)

Ken will focus his comments on two issues. As a geneticist and director of a large EU Horizon 2020 scientific project for disease vector control (INFRAVEC2), Ken would like to offer some rationale as to why he thought it important to involve social scientists and humanists in this project. What might be the main contributions that non-biologists can make toward an ostensibly scientific and technological project aimed especially at mosquito (and other arthropod) control? LERU, a consortium of European research universities has noted that "The concept of health has important cultural, social, behavioural and psychological dimensions, which are not mentioned in the [general] Horizon 2020 proposal" (LERU, Advice Paper, 11; June 2012). He is of course keenly interested in how natural scientists can, in turn, contribute to mainly social scientific and humanistic research projects aimed at human disease control.

The other issue that Ken wants to discuss is the political economy of vector research and control, as when EU and US funders are increasingly pushing scientists—including vector biologists—into profit-driven and immediate translational outcomes. Such expectations for immediate outcomes favor the development of certain kinds of technological tools that may not be the best solution to vector control, or utilize the most appropriate technologies, but that may be the flashiest. The end result can distort the products that emerge. Social science and humanist integration into insect vector research, and the qualitatively distinct kinds of knowledge they contribute, can help provide a balancing equilibrium that will ideally offer insight to guide more effective research and develop it in directions that are realistic, ethical, historically and culturally rooted, and that people may actually accept, use or implement.

Eva Veronesi (medical entomologist, University of Zurich)

Vectors without borders: the importance of communication and networking for a global vector control

In a time where globalisation has become an important topic of discussion with the increasing movement of people and goods, here's when the dispersal of vectors through passive transportation by human made activities has to be taken in great consideration.

Preparedness on vector control, and on the spread of the diseases related to the pathogens they may carry, is a crucial aspect. The scientific community, government, NGOs and stakeholder in general are the big player on this and on its realization. Furthermore, we should not forget the importance that the local communities have to make sure that all the efforts and resources spent are effective and sustainable. The involvement of local communities through "vector control education" programmes is becoming more and more recognized as the resulting increase of many activities not only aimed to their education but also with actions the citizen can contribute with. Moreover, any kind of vector control approach, from the most innovative tools on the release of modified organisms, to the basic one on manual removal of artificial vectors' breeding sites, needs to be embraced by the local community if we want it to be successful especially in a long term.

With this presentation we will explore different worldwide aspects and activities that are in operation involving both the local communities, schools, NGOs, scientists and government. Furthermore, it will be here discussed the importance of communication with the local community and between the scientific community and stakeholders, creating synergies and improving collaboration through networking actions.

James Webb (health historian, Colby College)

Historical Ecology and Mosquito Control

The Mosquitopia conference explores the idea of a balanced relationship between human beings and mosquitos and raises concerns about the possible imbalances in ecological relationships caused by interventions with insecticides, genetic engineering, and other forms of mosquito control. One approach to bringing greater specificity to these concerns is to investigate the ecological impact of major mosquito control/eradication efforts in the past. What ecological changes have ecologists and medical/public health specialists documented about past mosquito control interventions? Were these changes short-term or long-term? By what criteria were the inteventions evaluated? Should we ask different questions today of the same data?

James L.A. Webb, Jr., "The First Use of Synthetic Insecticides for Malaria Control in Tropical Africa: Lessons from Liberia, 1945-1962," Journal of the History of Medicine and Allied Sciences, vol. 66, no. 3 (2011), 347-376.

James L.A. Webb, Jr., "*Aedes aegypti* Suppression in the Americas: Historical Perspectives," Lancet, 6 August 2016.

Gordon Patterson. The Mosquito Crusades: A History of the American Anti-Mosquito Movement from the Reed Commission to the First Earth Day (New Brunswick: Rutgers University Press. 2009).

Gordon Patterson, The Mosquito Wars: A History of Mosquito Control in Florida (Gainesville: University of Florida Press, 2004).

Anna Wienhues (environmental ethicist, University of Zurich)

Environmental Ethics and Disease-carrying Mosquitos: Between a Rock and a Hard Place

If it were possible, should we eradicate all disease-carrying mosquito species? The short answer is: it depends. Contrary to what was implied by the BBC and Nature articles suggested as background reading for this symposium, this question constitutes a considerable normative challenge for many environmental ethicists. On the one hand, ethicists with rationalist commitments would not be satisfied with simply dismissing the mosquito's place in the ecosystem as a 'romantic notion' (c.f. Fang 2010:434). On the other hand, (bio- or ecocentric) environmental ethicists who think that we can find many more valuable attributes in nature than sentience only in terms of the capacity to suffer pain will also not be very impressed by the possibility of pain-free 'specicide' (c.f. quotes of Judson and Pugh in Bates 2016; and in more detail Pugh 2016). In the end, any comprehensive answer to this question will involve a complex set of moral trade-offs. In some cases, the eradication of a disease-carrying species will be morally justified, but as with many difficult cases it will leave a residue that a moral agent should identify as having lost something of moral significance.

Different theoretical commitments will lead to different problem settings, so I aim to provide a fairly inclusive picture in order to cover a range of issues that are relevant in environmental moral theorising. I will briefly illustrate what I think are some pressing ethical considerations that might, but not necessarily, count against species eradications in this context.[10] That means that I take as given that the eradication of certain mosquito species would be of significant benefit (at least in the short term) to many people and animals living in the areas of their spread. This constitutes the main – and weighty – reason for eradication due to the fundamental interests to life and health at stake.

Firstly, as biocentrist like myself will argue, focusing on sentience alone oversimplifies the moral landscape, because all living beings matter morally in themselves, meaning that the life of each individual mosquito is morally considerable and should be accounted for in our moral deliberations (e.g. in terms of its rights or intrinsic value). In the case of planning the eradication of several species, there are many individuals to take into account. A commitment against moral anthropocentrism entails that also the wellbeing of even such annoying and dangerous beings such as aedes aegypti has to be acknowledged. Furthermore, being a holder of moral status (in terms of being morally considerable) is not enough to explain the full moral context, and thus does not sufficiently explain what we should and should not do (see for a 'political non-ranking' account of biocentrism Wienhues, under contract).

Secondly, besides the moral status and related intrinsic value of each mosquito, also each mosquito species might be attributed intrinsic, relational and instrumental value (e.g. see O'Neill 1992 for an overview of different kind of intrinsic value). Only its instrumental value refers to its usefulness for nature and consequently humans, in terms of what some call 'ecosystem services'. That means that some positions attribute to each species moral value (which is not identical to moral status) that is independent of any usefulness it might have. Yet, whether a species can have intrinsic value is even more contested than the claim that individual living beings matter in themselves. But a 'species' might also be a shorthand for indicating other types of value, such as the value of non-human 'otherness' that might be embodied in appreciating biodiversity, the value of a certain kind of 'naturalness' as the product of non-human productive processes, or as 'natural historical' value (see

[10] That means that I will put aside other morally relevant considerations, for example, regarding the intersection of several normative issues such as historical injustices, public health ethics, food security, the legitimacy of such large-scale interventions for democratic accountability, the responsibility of scientists, and 'ecological' justice (that is, the justice entitlements of nonhumans).

for an overview Sandler 2012). Regarding the latter, Holmes Rolston III argues that each extinction is a kind of 'superkilling' (1995, p. 523) because 'a biological species is not just a class. A species is a living historical form […] propagated in individual organisms, that flows dynamically over generations' (1985, p. 721). Accordingly, each mosquito species arguably has more than the value of its niche in the ecosystem and is therefore, morally speaking, nonreplaceable even with similar non-disease-carrying mosquitos.

Thirdly, one might ask whether the eradication of a species is compatible with a commitment to an environmental virtue ethic which includes something like humility as a central attitude towards nature built into a theory of human wellbeing. For some, plans to eradicate several mosquito species might appear hubristic akin to plans to 'solve' climate change by means of geoengineering. (Eradication) technologies that use techniques of genetic modification might be most suspicious from such a perspective due to the 'depth' of intervention, because they go against a 'hands-off' tendency in environmental ethical theorising which is often put in terms of 'respect' (for a general discussion of 'respect for nature' see Taylor 1986).[11] However, fourthly, many environmental ethicists come more and more to terms with the need to move away from focusing on hands-off preservation to acknowledging the potential of intervention biology for environmental protection purposes. Yet one might still be inclined to favour the precautionary principle in light of the risks involved in any such intervention (even if done for purely human-focused reasons) which is intertwined with empirical questions.[12]

Even if all these four points were to hold in favour of the mosquitos, does not the eradication of such species rather simply constitute an instance of self-defence, which many environmental ethicists (e.g. potentially Sterba 1998, Taylor 1986) would deem to be fully morally justified? Yes and no. On the one side, it is a clear case of self-defence where a large section of humanity tries to justifiably defend itself (or on behalf of other living beings) from an aggression against its heath and lives. Excluding some forms of genetic modification, killing is often the only way to fend of such aggression if it comes from entities that 'cannot be argued with' and are 'innocent' in the sense of having no awareness of the consequences of their actions. However, despite that all mosquitos that feed on human blood cause irritation, the dangerous 'predator' that is targeted for eradication in this case is the disease (e.g. the virus) that they carry. So, one way of framing the issue would be to consider the eradication of the mosquitos as a problematic by-product of the eradication of the diseases in question. That would be closer to a case of killing a bystander or hostage which carries a bigger moral burden. If that is an appropriate representation of the problem at hand, then it becomes more a case of the moral acceptability of negative externalities of an act of collective self-defence, rather than a straight-forward case of self-defence itself.

As briefly illustrated, proposals to eradicate all disease-carrying mosquitos involve a range of different moral considerations and whether they are all-things-considered the morally 'right thing' to do depends on weighting a range of relevant considerations against each other. Assuming that the eradication of a mosquito species turns out to be justified, taking the other relevant moral

[11] There exists an extensive body of literature on the ethics of synthetic biology that I have to omit here (e.g. Deplazes Zemp 2012). Yet, even if genetic engineering (in whatever form) is considered to be not prima facie morally problematic, then that would still allow us to prefer techniques that allow the further existence of the mosquito species over techniques that are designed to eradicate the species, all-things-considered.

[12] Jonathan Pugh (2016), who does not find the 'hubris objection' convincing, also argues that a better understanding of the potential effects and success of mosquito eradication will be important to make a well-informed moral decision. I concur with Pugh's claim that 'epistemic humility' (p. 580) does not involve the dismissal of biotechnology based on it having some risk. Yet, the irreversibility of gene drives is definitely a risk to take into account.

demands seriously will involve an awareness that something of moral significance has been lost. An environmental ethical theory that dismisses such a loss oversimplifies the complex and conflictual moral decision-making at play, even when we have very good reasons to defend our own health or the health of 'domesticated' animals.

On a last note, importantly, the justification of such eradications is, of course, also highly dependent on the existence of morally (more or less) preferable alternatives. For example, if it is possible to combat diseases such as Malaria, Dengue Fever or the Zika virus with vaccines, genetic modifications that 'only' modify the species, or by transferring certain bacteria onto mosquitos in order to inhibit their ability to spread diseases, then these seem to be, on the first view, preferable options from the point of view that the eradication of a species is never morally neutral. Thus, if such alternatives are viable (and especially because the eradication of disease-carrying mosquitos seems also to be not possible presently), then the debate should be about whether there are moral demands – e.g. in terms of global justice – to fund such alternative efforts (via a global fund or similar) to reduce the health risks of such diseases for several billion people.

References

Bates, Claire. 2016. 'Would It Be Wrong to Eradicate Mosquitoes?' BBC New Magazine, 28 January 2016, Online edition.

Deplazes-Zemp, Anna. 2012. 'The Moral Impact of Synthesising Living Organisms: Biocentric Views on Synthetic Biology'. Environmental Values 21: 63–82.

Fang, Janet. 2010. 'A World Without Mosquitoes'. Nature 466 (News Feature): 432–34.

O'Neill, John. 1992. 'The Varieties of Intrinsic Value'. The Monist 75 (2): 119–37.

Pugh, Jonathan. 2016. 'Driven to Extinction? The Ethics of Eradicating Mosquitoes with Gene-Drive Technologies'. J. Med. Ethics 42: 578–81.

Rolston III, Holmes. 1985. 'Duties to Endangered Species'. BioScience 35 (11): 718–26.

———. 1995. 'Duties to Endangered Species'. In Encyclopedia of Environmental Biology, edited by W. A. Nierenberg, 1:517–528. Academic Press.

Sandler, Ronald L. 2012. The Ethics of Species: An Introduction. Cambridge University Press.

Sterba, James P. 1998. 'A Biocentrist Strikes Back'. Environmental Ethics 20 (Winter): 361–76.

Taylor, Paul. 1986. Respect for Nature: A Theory of Environmental Ethics. 25th Anniversary Edition (2011). Princeton: Princeton University Press.

Wienhues, Anna. Under Contract. Ecological Justice and the Extinction Crisis (working title). BUP.