Mosquitopia? The Place of Pests in a Healthy World

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It is fair to say that mosquitoes have inflicted more misery on human beings than any other animal, with at least one-seventh of humanity set to contract mosquito-born diseases this year. As a result, people have developed and are developing a range of powerful and high-tech measures to cope with mosquitoes either through prophylaxis, control or eradication—though to date with limited successes since malaria, Chinkugunya, Zika, West Nile, Dengue, and Yellow fever still rage. And yet, many ecologists and other scientists remind us that mosquitoes are also integral members of ecosystems, serving as fodder for fish, birds and bats, driving animal migrations, pollinating flowers, and much more. The diseases that mosquitoes transmit, not only to humans, but to other mammals and many other blood-filled creatures, clearly play critical roles in a range of ecological and evolutionary processes—and crucially, may also build resistance to other transmissible diseases. So even if most of the 3000 species of mosquitoes are harmless to people, those dangerous species of *Anopheles, Culex* and *Aedes* may still deserve a seat at the table, whether or not humans are the host. „I favor insect control in appropriate situations," the great naturalist Rachel Carson once declared, even if the question that obsessed her to the end of her days was „whether any civilization can wage relentless war on life without destroying itself, and without losing the right to be called civilized." Mosquitoes present us with a supreme case for finding how to simultaneously promote human and ecosystem health. With 2019 being the 120th anniversary of Ross & Grassi's discovery of the mosquito transmission of malaria, our goal at this symposium was to identify the best balance between managing for human health and environmental health.

The three-day symposium therefore brought together scientists and humanists to assess how mosquitoes can better coexist with people. The 27-person multi-disciplinary conference included several members of the EU-Horizon INFRAVEC2 research team dedicated to vector control; environmental humanists from the Rachel Carson Center in Munich; and other leading vector scientists, medical humanists, health historians and philosophers. Can we now learn to live with mosquitoes without them ultimately killing us or us killing them, thereby allowing us to enter a new age of Mosquitopia?

In the first opening lecture, NANCY LEYS STEPAN (Columbia University New York) suggested that *eradication* – as a concept and practice – is doubtful. Regarding eradication, three questions should be raised: Could we? Would we? Should we? Complete eradication, in her opinion, is neither feasible, nor desirable, and not useful from a public health point of view. Taking Brazil as an example, Leys Stepan demonstrated how „all dreams die hard", as dreams of mosquitoes eradication prevailed there from the days of Fred Soper in the 1930s to the Zika epidemic of 2016: in spite of ongoing governmental zest for eradication and recurring attempts at eradication, mosquitoes are still very well present in Brazil. However, could, should we eradicate mosquitoes? Beyond the immediate ecological implications, one should take good care of the wide social and political aspects of such attempts. An alternative to eradication attempts might be re-modeling of public health around social-ecological methods for living with mosquitoes. We should concentrate on 'control' of mosquitoes, 'reduction' of their populations and 'learning' to live with them, rather than try to eradicate them altogether. Regarding historical research of the field, she opined that many archives dealing with mosquitoes – and health issues in general – are simply neglected and are not being used.

In the second opening lecture, WILLEM TAKKEN (University of Wageningen) focused on the side of anthropophilic mosquitoes, vectors of malaria, Zika, chikungunya, dengue and lymphatic filariasis. Referring to Ronald Ross's 'The Mathemat-

ics of Malaria' (1911), Takken reminded us that all malaria control efforts finally boil down to „making sure you are not bitten". Takken periodised human efforts to combat mosquitoes into several stages: 1900 – 1930: environmental methods (species sanitation); 1930 – 1945: larval control (Paris green, quinine); 1945 – 1969: drugs (chloroquine etc.) and insecticides (DDT, dieldrin, malathion); 1970 – 2000: drugs (mefloquine, artemisinine). Malaria is the most serious disease transferred by mosquitoes by numbers of victims. In accordance with the WHO declaration from August 2019 that the chance of elimination of malaria is very small and that it can probably only be reduced, Takken suggested that our goal should be malaria 'management', preferably by environmental measures: as insecticide resistance presents a growing threat, better methods may include water management, biological control (predation, entomopathogenic fungi), genetic modification and traps.

Referring to the sub-title of the workshop, CHRISTOF MAUCH (Rachel Carson Center Munich) commented that our world is not a healthy one. The question of eradication is an ethical issue, and as is often the case in ecological questions, everything is connected with everything else. Recollecting Rachel Carson's insight from the early 1960s about human health, Mauch mentioned that the bodies of people today are different from the bodies in 1962, after decades of exposure to pesticides: it has a lot to do with politics, not only with chemicals.

Coming from the natural sciences side, KENNETH VERNICK (Pasteur Institute – Paris) said that social science and biological messages are closely intertwined. Natural scientists tend not to research concepts. He stressed that incorporating social knowledge should not take place only during the implementation of public health policies, but already during the design stage of field projects and even research. There is a need for a bottom-up approach regarding aims, methods and solutions. Hitherto, technical decisions were often made before understanding the real needs of people(s) in the field. With market-driven technological fix-up approaches, both private and governmental funds are often prone to „short-termism", searching for quick, immediate and „flashy" solutions. Technologies with old and proven track record of success may be neglected because those are not fashionable or profitable. There are corporate interests in it, and mosquitoes are just the front line, poster-children of an entire industry, profitable new technologies of genetic driving and corporate enterprise.

In a similar vein, ALEX NADING (Brown University Providence) asserted that there are lots of similarities between countries in different parts of the world in their attitudes towards mosquitoes. These similarities point to more general and global issues of human perception of the environment, as well as humans' relation to themselves. As we now deal with the threat of a global wave of extinction, we should bear in mind that eradication is an intended attempt at the extinction of a species. The attitude towards mosquitoes is well connected to political stances: different political regimes had different control and public health strategies (specifically, Nading brought forward the example of the Sandinistas in Nicaragua, one of his main field sites). However, one major feature of health policies today is the narrow visioning and framing of problems: food, sickness, etc. This particular perspective replaces a holistic view of human and environmental health.

A natural scientist as well, ISABELLE DUSFOUR (Pasteur Institute – French Guiana) offered her insights as an entomologist („mosquitologist") working in French Guiana, dealing with filariasis, dengue, malaria, yellow fever, chikungunya, Zika, mayaro, and Tonate. It is interesting to note that the local population there does not seem to be concerned about malaria and dengue. A political-economic dimension, however, was presented as south American producers and suppliers of treated bed-nets find it non-profitable to distribute their products in Guiana because of the high costs of complying with EU regulations.

Also from the point of view of entomology, FRÉDÉRIC SIMARD (IRD Montpelier) provided a general review of the more than 3,500 different species of mosquitoes, only few of which are dangerous to humans. Mosquitoes

are connected to human populations, and human-shaped environments give home to different kinds of mosquitoes. For example, *Anopheles gambiae* has an anthropophilic biting behaviour, rests indoors and lay eggs in sunny places with no vegetation. Therefore it is present mostly in sunny, wet places with humans, i.e. countryside. *Aedes albopictus* has different preferences, and therefore will be found more in urban areas. Two main problems in our current dealing with mosquitoes are that scientists generally do not publish negative results, and public health experts are hardly interested in environmental factors beyond the human body.

But what do we actually mean when we refer to „mosquitoes"? Taking the history of *Aedes aegypti* – the infamous vector of viruses, including Zika, dengue, chikungunya, and (urban) yellow fever – in Brazil, LUISA REIS CASTRO (MIT Cambridge) deconstructed the general, amorphous categorization of mosquitoes. „Mosquitoes" are a total generalisation, and it matters which humans and which mosquitoes we have in mind. Who exactly considers mosquitoes as pests? Why are they considered as pests, where and under which historical conditions? By zeroing in on 'A. aegypti', Reis Castro showed how it has been framed, perceived and tackled in varying ways.

Indeed, we do not like mosquitoes, but mosquitoes like us, PETER COATES (University of Bristol) asserted. Within this framework, we have scored several own goals, as historical attempts to eliminate mosquitoes or to control them proved to be counterproductive, actually enhancing mosquitoes' immunity to pesticides or making them find new survival strategies. All together, however, today mosquitoes in temperate climes are usually a nuisance, not a lethal threat. Furthermore: can we talk about eradication and control of mosquitoes without accounting for other pests (as rats, for example)?

But should nuisance be overlooked? While concentrating mostly on human health and anthropophilic mosquitoes, EVA VERONESI (University of Zurich) reminded us that animal health is different from human health, but still an issue. Are mosquito-borne diseases primarily an animal health problem or a human health problem? Should animals' problems with mosquitoes be regarded as mere „nuisance", or rather as a deeper problem? Another point is that, on the global level, the WHO is an advising organisation, not an implementing one. We currently need better drugs (including a better evaluation of costs of drugs and vaccinations), better politics, with a higher level of knowledge among decision makers, and better public awareness for mosquitoes and the diseases they transmit.

Pointing out several instances of rebounding malaria, MELISSA GRABOYES (University of Oregon) is currently conducting research funded by an NSF grant with students in Zanzibar, re-examining the findings regarding rebound malaria presented by Cohen et al.'s article from 2012. Apparently, rebound malaria has been deeply underestimated in the past. New data reveal that the re-emergence of malaria is higher than suspected, and is closely linked with social, economical and political factors. An important issue related to the successful dealing with malaria in the field is the notion of consent among people involved: both politically and personally.

HELMUT LEMKE (WetlandLIFE project – Greenwich) agreed that transferring knowledge into action is a political question. Policies are made through education. We have to change politics, but how do we reach the public? Together with KERRY MORRISON (WetlandLIFE project – UK), he presented the ways in which artists contribute to the wider dissemination of knowledge and the raising of awareness among people in the United Kingdom, as part of a project aimed at protecting wetlands. In their case, it was through short films and performance art. As an advisor on their project, FRANCES HAWKES (University of Greenwich) reminded us that mosquitoes are not only vectors of disease. From the over 3,500 species of mosquito on earth, only a small handful can carry the pathogens that cause human disease and it is these species which have been studied most intensely. For the purposes of public health, the substantial body of research on mosquitoes has helped us to understand mosquito-borne disease transmission and informed the development of mosquito – and

disease – control methods. But parallel to this, a fascinating and complex biology has been revealed, showing the mosquito's incredible and unusual behavioural, anatomical and physiological traits. As such, they have important ecological and environmental roles, beyond disease. In a militant context, Sun Tzu recommended to „know the enemy and know yourself". We know the mosquitoes – to no avail; but do we know ourselves, as part of the web of which we both make part?

Again from a historical perspective, JAMES WEBB, Jr. (Colby College Waterville) noted that the same organisation (Centers for Disease Control, CDC) was doing the same things for eradicating mosquitoes several decades apart, repeating the same mistakes and the same failures. Therefore, there is a need for training public health experts in history. Rebound malaria – which we witness today in several regions – can be overcome if one has a functioning basic public health system, with treatments and medications. The problem is that donors are not keen of giving money to long-lasting projects. Another important yet neglected prism is that of race: people in Guiana, for instance, are not „white"; if „white" people were there, the entire attitude would have been different.

From an ethical and philosophical perspective, RAMYA RAJAGOPALAN (University of California – San Diego) referred to the ethical and political-economic aspects of new and innovative mosquitoes fighting technologies, especially the novel „Gene Drive" technique. „Let's eradicate malaria" was and is an idea framed by rich people in technologically advanced countries, but current malaria patterns are not disconnected from any historical economic context: they are the outcome of historical political processes, disadvantaging parts of the globe. Will Gene Drive prove to be the same? Furthermore, precise genetic modification of mosquitoes may prove to be the edge of a „slippery slope" leading from altering mosquitoes to altering other species. How about altering the genetics of other humans? „Designer mosquitoes" might challenge our ideas about the appropriate scale and scope of human intervention in entire planetary ecosystems. On the other hand, our living with diseases shape us as humans all the time.

From an ethical aspect, ANNA WIENHUES (University of Zurich) reviewed the relations between environmental ethics and disease-carrying mosquitoes. With an analytical philosophical approach, Wienhues referred to 5 different sets of considerations. First is biocentrism: all living beings are morally considerable, and living beings hold an intrinsic attribute of well-being, as every individual living being has importance. Secondly, ecocentrism: emphasising the moral value of entire systems, where each species has intrinsic value (and instrumental value for the system). Intrinsic value here implies non-replaceability of the species. Thirdly, environmental virtue ethics, seeing humility as a central attitude towards nature built into a theory of human well-being (as opposed to hubris, for example). Fourthly are intervention and risk, presented by the precautionary principle; this is „epistemic humility". Finally there is the perception of Human versus Mosquitoes: a case of self-defence OR a case of negative externalities of an act of collective defense (the enemy being the parasites, more than the mosquito).

On the practical side of dealing with mosquitoes, ANDREAS ROSE (Biogents – Regensburg) presented not only different traps for mosquitoes, which avoid the use of insecticides, but the entire research, evaluation and development process which allows preventing mosquitoes from transmitting diseases in various environments and situations. A „one big shot" approach to all mosquitoes is less likely to succeed than an informed and targeted prevention. Here again, the importance of precision and the futility of generalisations was shown: there's a plenty of mosquitoes requiring different traps, and creating better mosquito traps requires adjusting them to the different species and scenerios. TOBIAS SCHIEFER (City of Munich) from the city of Munich emphasized the importance of healthy wetlands for producing healthy insect populations, which include mosquitoes, also within city boundaries.

The entire workshop was filmed and photogrpahed by SAMER ANGELONE (University of Zurich), who is currently making a film about mosquitoes, our relation to them and

the ways in which we perceive them. Also through visual means, ADRIANA FORD (Imperial College London) presented remotely her film about the interviews she conducted with British wetland users, as part of a wetland preservation project in Britain. One important element that was mentioned only briefly at the workshop was the economic dimension of our relations to mosquitoes. A universal human related phenomenon and challenge, the global political economy of mosquitoes as disease vectors should also be researched, as it has implications on our entire coping with these animals.

Mosquitoes, unlike many insects, seem to be expanding rather than contracting in many locations around the world, due to habitat and climate changes. Naturally, the term „Mosquitoes" is a complete generalization, as there are thousands of known mosquito species, only a several of which are the vectors of diseases. The general consensus at the meeting was that control was more realistic and more desirable to eradication, despite this view being counter to policies of certain health NGOs. For the past 70 years, attempts to completely eliminate mosquitoes has failed. Are we able and willing to learn to live with mosquitoes? The participants of the workshop are now working on an article and a book about this question.

Conference overview:

Marcus Hall (University of Zurich/Rachel Carson Center) / Dan Tamir (University of Zurich): Welcome

Samer Angelone (University of Zurich): Making better mosquito films

Peter Coates (University of Bristol): Just a troublesome nuisance?

Isabelle Dusfour (Pasteur Institute – French Guiana): How could we rethink control of arboviral diseases?

Adriana Ford (Imperial College London): Local perceptions towards mosquitoes and mosquito risk in English wetlands

Melissa Graboyes (University of Oregon): Remembering Malaria Elimination Failures in Zanzibar, 1920-2019: Arguments Against Mosquito Eradication

Frances Hawkes (University of Greenwich): 'Know your enemy and know yourself and you can win a hundred battles'

Helmut Lemke (WetlandLIFE project – UK): Itching for Understanding: Living with Mosquitoes

Christof Mauch (Rachel Carson Center Munich): Some Comments on Control and Eradication

Kerry Morrison (WetlandLIFE project – UK): Itching for Understanding: Living with Mosquitoes

Alex Nading (Watson Inst. for International and Public Affairs, Brown University): Eradication against Ambivalence

Ramya Rajagopalan (University of California – San Diego): Gene drives, designer mosquitoes, and the networked „nature" of interspecies relationships

Andreas Rose (Regensburg): Creating a better mosquito trap

Luísa Reis-Castro (MIT): Placing Mosquitoes as Pests: the many Aedes aegypti in Brazil

Tobias Schiefer (Munich): Wetlands, Mosquitoes and the City

Frédéric Simard (IRD Montpelier): Mosquitoes Controlling Mosquitoes

Nancy Leys Stepan (Columbia University): „Could we, Should we? Ridding ourselves of mosquitoes forever"

Willem Takken (University of Wageningen): „Could we, Should we? Ridding ourselves of mosquitoes forever"

Kenneth Vernick (Pasteur Institute – Paris): Mosquitoes and public health

Eva Veronesi (University of Zurich): Vectors without borders: the importance of communication and networking for a global vector control

James Webb Jr. (Colby College): Historical Ecology and Mosquito Control

Anna Wienhues (University of Zurich): Environmental Ethics and Disease-carrying

Mosquitos: Between a Rock and a Hard Place

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