
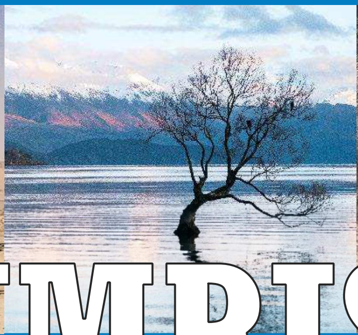


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Climate related impacts on natural and human systems

ORAL

Mosquito-borne infections in Europe: Assessment of public health risks via temperature-driven mathematical models

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Climatological variables are critical drivers in infections transmitted by mosquitoes, acting at multiple levels on the biology of the mosquito life cycles but also on epidemiological traits of the viruses such as the incubation times and transmissibility. Therefore, the impact of climate change on the risks for public health can be profound. Mosquito-borne infections represent a significant fraction of disease burden worldwide and are emerging or re-emerging as an important threat for human health. Diseases such as chikungunya and dengue are rapidly expanding their geographic range well beyond the tropical and subtropical belt. In Europe, the first recorded episode of chikungunya transmission occurred in Emilia Romagna, Italy, in 2007, and resulted in a large outbreak involving over 200 patients; in the summer of 2017, another outbreak of more than 400 cases originated in Anzio, involving neighboring cities including Rome, and seeding an additional outbreak of over 100 cases in Guardavalle Marina, Calabria. Sporadic transmission of chikungunya has also been recorded in

Southern France in 2010, 2014 and 2017. Dengue had been absent from Europe since 1928 until the summer of 2010, when small outbreaks took place in France and Croatia. In 2012, the Portuguese island of Madeira witnessed a major outbreak with over 2000 cases; further sporadic cases of autochthonous dengue were more recently reported in France. Meanwhile, in the rest of the world, Zika has emerged as a new pandemic threat with severe congenital syndromes; outbreaks of Zika appeared in 2007 and 2014 in insular countries of the Pacific, then in 2015 it reached Brazil from which it spread explosively to most areas of Central and South America. Although Zika infection in humans is generally asymptomatic or very mild, it is capable of causing Guillain-Barre' syndrome in adults and congenital neuronal defects in newborns from mothers infected during pregnancy. Finally, large and deadly yellow fever outbreaks have occurred in Angola, Democratic Republic of Congo and Brazil since 2016, in spite of the major reductions achieved with the introduction of an effective vaccine since the '90s.

Mathematical and computational models can play an important role to assist public health systems and decision makers, by allowing the estimation of potential transmission risks to humans and the cost-effectiveness of preventive interventions under a range of temperature scenarios. In this presentation, we will showcase a number of practical applications of models to mosquito-borne infections accounting for temperature changes over time and under different scenarios of temperature change.

To estimate transmission risks of tropical diseases in Northern Italy, we developed a mathematical model representing the dynamics of Aedes albopictus populations throughout the whole developmental cycle (eggs, larvae, pupae, female adults). The model was fitted to mosquito capture data from ten municipalities in the provinces of Trento and Belluno across the mosquito seasons of 2014 and 2015. We found a significant risk of chikungunya outbreaks in most sites if a case was imported from endemic areas between the beginning of summer and up to mid-November, with an average outbreak probability between 4.9% and 25%, depending on the site. A lower risk was predicted for dengue, with an average probability between 4.2% and 10.8% in a restricted window of importation (between mid-July and mid-September). These risks would be enhanced by potential rises in temperatures, doubling for scenarios envisioning a 2-degrees daily increase, furthermore, the time span of the year where outbreaks could occur would also increase significantly, with large site-specific variations. We later used the same estimates on mosquito abundance to provide a timely risk assessment during the Zika pandemics in 2016, highlighting a consistently low risk of autochthonous mosquito-borne transmission in Northern Italy (as long as the vector competence of Aedes albopictus remains at the currently measured levels). In a separate study, we then moved on from the assessment of transmission probabilities to estimate the potential size of chikungunya and dengue outbreaks. We also evaluated the ability of preventive approaches to reduce transmission risks and outbreak sizes and we analyzed its cost-effectiveness. We found that routine larviciding of public catch basins can limit both the risk of autochthonous transmission and the size of potential epidemics. Ideal larvicide interventions should be timed in such a way to cover the month of July. Optimally timed larviciding can reduce locally transmitted cases of chikungunya by 20%-33% for a single application (dengue: 18-22%) and up to 43%-65% if treatment is repeated four times throughout the season (dengue: 31-51%). In larger municipalities (>35,000 inhabitants), the cost of comprehensive larviciding over the whole urban area overcomes potential health benefits related to preventing cases of disease, suggesting the adoption of more localized interventions. Small/medium sized towns with high mosquito abundance will likely have a positive cost-benefit balance. Involvement of private citizens in routine larviciding activities further reduces transmission risks but with disproportionate costs of intervention.

Similar approaches were applied to analyze in real-time an actual outbreak, namely the 2017 chikungunya outbreak in Anzio. Using entomological capture data collected in 2012 from 18 sites along a 70 km-transect from the Lazio coast (four sites) to rural inland areas, and temperature data from 2017, we estimated the mosquito population densities. We coupled these estimates with data on human landing captures to estimate the mosquito biting rate and computed the probability of outbreak and outbreak size for different time of the year in the region. We identified the time of likely introduction of the index case (first week of June in Anzio, range: 21 May-18 June; early July in Rome, range: 28 May-16 July). We estimated a higher risk of large outbreaks in coastal and rural sites than in urban sites, despite the high vector abundance in some urban areas, and a significant probability of observing additional transmission up to mid-November (later confirmed by observations). We also quantified the probability that infected blood donations might have been occurred during the outbreak and total health and economic burden for the outbreak in Lazio. Based on the same mosquito abundance estimates in Lazio, we evaluated the probability of yellow fever outbreaks transmitted by Ae. albopictus in case of importation of an index case from areas of the world with active transmission. We found that the risk of transmission is generally low and limited to sporadic cases. However, for some coastal and rural sites there is a nonnegligible potential for large outbreaks, especially if importation occurs during the second half of July.

These applications elucidate the different ways in which data-driven modeling can contribute to decision making in public health, in order to face the growing threats of mosquito-borne infections and to assess the potential impact of climate change on these estimates. The extraction of valuable information from data and temperature projections is critical for preparedness and optimal resource assessment.

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