PLOS Science Wednesday: Hi reddit, my name is Lillian and my research in PLOS Biology shows how temperature shapes mosquito and malaria parasite traits – Ask Me Anything!

PLOSScienceWednesday [1] and r/Science AMAs[1]

[1]Affiliation not available

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Abstract

Hi Reddit, My name is Lillian L. M. Shapiro and I am a postdoctoral scientist at Vanderbilt University. My research focuses on how environmental changes affect the biology of mosquitoes and the diseases they transmit. I recently published a methods & resources study titled "Quantifying the effects of temperature on mosquito and parasite traits that determine the transmission potential of human malaria" in PLOS Biology. This work was part of my PhD studies and concerns how temperature shapes mosquito and malaria parasite traits, and how changes in these traits impact malaria transmission. We found that warmer temperatures increase the potential of malaria transmission up to about 26ºC (79ºF), but temperatures hotter than this may actually decrease risk, suggesting that the range where malaria can flourish could shift geographically under predicted climate change scenarios. I will be answering your questions at 1pm ET. Ask me Anything! EDIT: Because this AMA started a little late, I can continue answering questions (today) beyond the normal 2pm ET cutoff, I just might be a little bit slower in responding.

the WINNOWER

REDDIT

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PLOSSCIENCEWEDNESDAY R/SCIENCE

Hi Reddit,
My name is Lillian L. M. Shapiro and I am a postdoctoral scientist at Vanderbilt University. My research focuses on how environmental changes affect the biology of mosquitoes and the diseases they transmit.
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You monitored mosquitoes who were placed in incubators set at various temperatures for prolonged durations of time. I see that your limitations section acknowledges real world temperature variability would likely have significant effects on mosquito mortality rate and likelihood of transmission. Do you have a weak hunch on what those effects would be, in terms of the optimal temperature for malaria's spread?

Is there any work that's been done on human behavior changing in response to temperature in the context of disease? I'm wondering if people will hide away from the sun more on days where mosquitoes are most likely to be dangerous, or maybe hide away when they shouldn't on days when the optimal temperature for malaria's spread has been exceeded. I know most people in Africa won't have bug-proof homes, but it still seems like this should matter.

entropizer

I'd expect several possible scenarios for effects of fluctuation: if the mean temperature is permissive to mosquito and parasite survival, the temperature could be fluctuating to the point it is too hot, and malaria risk is less than expected. Conversely, fluctuating towards a cooler end could create a "rescue effect", which could also have detrimental effects on prediction if the predicted risk was larger than expected. (check out this paper in PNAS by some former colleagues for some further info!).

Another limitation (beyond logistics we mentioned in our discussion) is that although we can estimate the "mean" diurnal temperature range (DTR), the actual DTR in the area where this mosquito & parasite species pairing occurs (India) ranges from +/- 2ºC to +/- 9ºC, meaning that picking a DTR that is truly "representative" of the landscape of malaria transmission in the region. However, a good follow-up project would be testing the same mean temperatures with a suite of different DTR's, such as mean +/- 2, mean +/- 4, etc. This would certainly be a long and involved project, but I'm hoping an intrepid graduate student enters the lab soon to continue our work!

Regarding human behavior, there's not much that I have seen aside from predictions concerning more large-scale patterns (e.g. over a period of decades, certain regions could become non-arable, and people that rely on local farming and livestock rearing would migrate towards regions that are permissible to crops/livestock). As far as human behavior with regards to this species, they mostly bite during the night, so one of the major concerns in a lot of areas is that when it is very hot during the day, folks open their windows if they don't have air conditioning, and in very poor areas, it is not uncommon to see open windows without screens, leading to mosquito entry and disease transmission when they don't have good mosquito nets. AC and screened doors/windows are two things that people in developed areas that are still permissible to malaria (think places like the SE United States and Mediterranean Europe) definitely tend to take for granted!

TL;DR Absolutely 100% 'yes', fluctuating temperatures will affect the transmission differently than just mean temperatures, but it depends on how much the temperature fluctuates. Re: human behavior, there is little research aside from studies on migration, and it is one of the many knowledge gaps in malaria research that we need to bridge.

What do you think would be important next steps in accurately predicting temperature effects on transmission rates?

jivester024

Great question – I think that the answers here are a mix of science and policy. On the science side, it's very important that we quantify how temperature could affect these same traits in other common malaria vectors. The species we used here is an Indian mosquito, but there are several different mosquito species in sub-Saharan Africa and South Asia that contribute a lot to malaria burden. Interestingly, we saw that our data for the thermal performance of traits differed from a modeling study using aggregated data from several species, suggesting species-specific effects. In addition, as u/entropizer mentioned, using this methodology to test how fluctuating temperature regimes shape these traits is crucial. We hope that the published work in PLoS Biology can help serve as an "experimental blueprint" for accomplishing these next steps.

On the policy side, many of us malaria/environment researchers are in desperate need of funding, especially for big projects like the fluctuating temperature work, which could take multiple years and require the labor of several people. Further, because most researchers in the United States are funded by government agencies (NSF, NIH, etc.), we are barred from any sort of activity that could be perceived as "lobbying" because we are already funded by govt agencies, and there isn't much of a research science lobby compared to other industries and interest groups. For reference, I'm currently supported by a private university endowment fund, so I'm comfortable talking about this kind of stuff, but even making a call to your local rep and talking about how important increased funding for disease research is can be a breach of contract if someone wants to get you in trouble with your funding agency. This is as 'political' as I will get on this AMA, but the policy surrounding this research is just as big (if not bigger) of a hurdle as the research itself.

TL;DR: more experiments exploring different species, fluctuating temperature and local adaptation/selective pressure of temperature; also, we need consistent, reliable funding to do this research and increased support from citizens and interest groups because we are not able to lobby on our behalf.

Disclaimer: I haven't read the paper.

Any idea how your results would change across generations?

In other words, one might expect a warming climate to exert a selective pressure that results in mosquitoes with transmission potential at higher temperatures different from what you observed. Whether that's a zero sum change or an increase in transmission potential.

NosemaCeranae

Haha, thanks for your honesty – not sure if you're a grad student or not, but I definitely perfected the art of "read abstract, briefly skim discussion, look at figures" as my way of "reading papers" during my PhD, and still now as a post-doc.

Your question serves as a great addition to the one asked by u/jivester024; local adaptation of different mosquito populations to warming temperatures is a big black box for vector-borne disease researchers; we don't really know 1) if local adaptation happens; 2) if it does, on what time scale; and 3) what is the physiological/molecular/genetic mechanism for the adaptation and does it have any costs [e.g., you can survive at hotter temps, but your thermal tolerance comes at the cost of fecundity or something like that].

Another possible outcome of local adaptation is species replacement – i.e. the species that is the most common vector for a specific disease in one region is replaced by a species that is better-adapted to that climate.

I wish I could give you an actual prediction, but I have literally no idea because there's so many possible scenarios. There's a great review about this by my former advisor and a post-doc in my former lab; my email is listed on the PLoS Biology paper and if you're interested in the review, just shoot me an email and I can send you a PDF. :)

P.S., do you study N. cerenae/microsporidians?

Thanks for doing an AMA!

Do you think it will be possible to combine your findings with, say, a heat map (perhaps that should be 'risk map') of the potential future spread of malarial vectors given certain climate change scenarios?

I think this would help demonstrate the increased risk of disease due to climate change in a digestible, media-friendly way.

TheMercian

I certainly hope that our data will assist in the construction of maps and other tools that are more easily understood by the public at large. Creating heat maps is a pretty tough modeling excursion, and *definitely* not in my wheelhouse, but there are quite a few excellent statisticians and mathematicians in the malaria research world that do this sort of thing all the time (check out the Malaria Atlas Project for more info). By publishing in an open-access journal like PLoS Bio as a 'Methods and Resources' article, we are hoping that both our methodology and sizeable dataset can lay the groundwork for building on our empirical studies but also providing good data for math/stats folks to use in their work.

I notice that your study was done with Anopheles stephensi - what made you choose this species of mosquito? And would you expect other malarial vector mosquitoes (like A. gambiae) to respond similarly?

RoliRoberts

We chose An. stephensi for a couple reasons; the first being that An. stephensi is a lot easier to work with than An. gambiae (An. gambiae in the lab is actually pretty sensitive and colony crashes are a lot more common than with An. stephensi, and because we needed thousands and thousands of mosquitoes for these experiments, we didn't want to take the risk of a colony crash). The second reason is that the lab I did this work in (Matt Thomas' lab at Penn State) works really closely with research institutions in both urban and rural India. Working with a species that lives in this area allows for an easier extension of our work to semi-field settings, in addition to data that those institutions (some of whom work for the Indian government) can use directly.

I'd expect An. gambiae to respond similarly in terms of the shapes of thermal performance functions, but our work compared to aggregated models that rely on mixed-species data shows some big differences, suggesting that these changes are species-specific. I currently work with An. gambiae at Vanderbilt (I'm still looking at environment, including temperature, but my work focuses on physiological and molecular mechanisms of aging, so the context is a lot different, but I'd expect that gambiae is much more sensitive to thermal changes compared to stephensi.)

TL;DR: We also have a lot of connections to Indian research groups, and An. stephensi is an important malaria vector in India, in addition to being easier to rear in the lab; our results suggest that these changes are species-specific, so An. gambiae will probably respond differently.

Thank you for the AMA!

With regard to the reduced risk at higher temperatures: was this due to the mosquitoes carrying a lower load, or due to the temperature of the infected individual being too high for the disease to thrive?

StonedPhysicist

It was a combination of several factors, but the main driver of decreased transmission potential at higher temperatures was definitely increased mosquito mortality. Most malaria models (as well as models of other vector-borne diseases) are super sensitive to changes in vector survival. Malaria models are especially sensitive due to the relatively long incubation period within the mosquito compared to faster developing pathogens like many arboviruses.

In addition, reduced parasite prevalence in high temperatures certainly contributed to the overall decrease in transmission potential. One of the most interesting findings in this paper was that we consistently observed parasite prevalence to decrease with time at temperatures of 30ºC and above. We hypothesize that this is due to differential mortality – i.e. infected mosquitoes die more quickly than non-infected ones at higher temperatures, but it's very possible there are other mechanisms at play, including parasite death, changes in mosquito immune proficiency, and even changes in mosquito cardiac physiology. Cardiac/circulatory function is often ignored when it comes to pathogen transmission. It contributes to the efficiency of the flow of pathogens to the salivary glands to be transmitted to the next host. This is because mosquitoes (and all insects) have "open" circulatory systems (i.e. no veins or anything, just a tubular heart surrounded by flowing blood called hemolymph).

How well do you feel incubators under constant temp/humidity reflect the "real world" in terms of malaria transmission? Even in tropical environments, both are cycling a fair amount each day, and no where has the constant 27C/85% humidity that every insectary uses.

bkraj

See my answer to u/entropizer above for a more expanded answer.

You are correct - there isn't anywhere in the real world that has constant temp or humidity. However, choosing a fluctuation regime that is an overall "accurate" representation of the area where the species we studied (Anopheles stephensi) is an important vector (urban India) is difficult. In the city of Delhi, for example, diurnal temperature range (DTR) can range from +/-2ºC to +/-9ºC (see Mohan et al. 2015 for example). In addition, in quickly urbanizing areas, we are seeing a steady decrease of DTR, which is likely due to factors like increased square mileage of pavement as opposed to greenspace. Another factor is where the mosquitoes are resting/feeding, which can be affected by the type of house (e.g. thatched roof vs. iron roof; see Cator et al. 2013 for data from our research partners in Chennai, India).

Regardless, answering questions about different DTR's is important, and represents a crucial next step in this research methodology. I get this question a lot, and it really seems like a cop-out answer for me to just say "logistics", but in terms of this research (n = >8500 mosquitoes for all experiments combined), we wanted to lay a foundation for solid methodology, a more biologically relevant model, and some evidence for species specificity first before exploring the complexities of DTR, so we felt first testing a wide range of mean temperatures would be a good start. Luckily, this was my last chapter of my PhD, so it's up to the next graduate student to do that project! (For reference, from conception to publication, this project took 2.5 years, but now that all the troubleshooting is complete, I'm hoping a grad student can re-do these experiments under a suite of DTR's).