Deforestation and malaria

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Deforestation Tied to Changes in Disease Dynamics

When a malaria outbreak erupted in Malaysian Borneo in 2002, researchers were surprised to find that the culprit wasn’t *Plasmodium malariae*, the main mosquito-borne parasite known to infect humans in the area. Instead, the parasite’s DNA turned out to stem from *P. knowlesi*, colloquially known as “monkey malaria,” which is specialized to infect and proliferate in forest-dwelling macaques. A few accidental cases had been recorded in people over the years, but such an outbreak was unusual. And it didn’t stop there: *P. knowlesi* has since become the most common cause of malaria in Malaysia, and human infections are steadily rising throughout Southeast Asia.

It’s one of several instances of vector-borne pathogens that have popped up in humans in areas that are undergoing widespread deforestation. The forests of Borneo are being felled at a rapid rate, foremost to make way for palm oil plantations. Researchers have long suspected that the process may play a role in human outbreaks of vector-borne diseases, including malaria, dengue, and others, and evidence is increasingly mounting in support of that idea.

“The more we’re disturbing this natural habitat, the more we’re shaking the pot,” says Amy Vittor, an epidemiologist at the University of Florida’s Emerging Pathogens Institute. With a range of diseases, “the links are becoming clear that disturbance leads to downstream emergence events” in humans, she says.

A string of recent reports has bolstered the link between forest removal and *P. knowlesi* outbreaks. In a study published this month (January 16) in the Proceedings of the Royal Society B, a group of researchers investigated whether the association holds true for a small patch of rainforest in Malaysian Borneo, where locals fell trees for small-scale agriculture. The team used satellite data to document the change in forest cover over four years, and had a machine learning model analyze the data to see if forest loss could explain the pattern of *P. knowlesi* infections.

The proportion of cleared land was a strong predictor of *P. knowlesi* occurrence within a kilometer of the clearance, the researchers found. “The evidence we have from this and other studies strongly supports the association between deforestation and *P. knowlesi* in this setting,” writes coauthor Kimberly Fornace, an epidemiologist at the London School of Hygiene and Tropical Medicine, in an email to The Scientist.

Catherine Moyes, a spatial ecologist at the University of Oxford’s Big Data Institute, cautions against making claims about causal links between deforestation and *P. knowlesi*, noting that the algorithm the team used isn’t capable of proving cause and effect. Nevertheless, there is evidence for an association. Through a similar approach in 2016, her model predicted that some of the mosquito vectors that carry *P. knowlesi* are
likely to occur in areas with forest disturbance. A separate statistical analysis by Fornace and her colleagues also found that *P. knowlesi* cases in humans were positively associated with forest loss over time.

The mechanisms that drive this relationship are unclear. Deforestation may simply be bringing humans into contact with forest-dwelling macaques and infected mosquitoes, as people move into cleared areas and macaques closer to human settlements. In addition, the clearing of trees may shift the locations of breeding sites for mosquitoes that thrive at forest edges. These mechanisms are thought to play a role in a range of vector-borne diseases. And as tropical forests are being felled worldwide at an alarming rate, scientists are becoming increasingly concerned that future pandemics may arise from humans’ destruction of forests.

Malaria and forests: An itchy relationship
The link between vector-borne disease and deforestation has been most thoroughly investigated in human-specialized forms of malaria. Some findings have been striking: One study estimated that a 4.3 percent increase in deforestation over a three-year timeframe was associated with a nearly 50 percent increase of malaria incidence in a small patch of Brazilian Amazon. In one large-scale analysis in 2017, researchers found a positive association between the rates of deforestation and malaria prevalence in 67 countries.

At the same time, other studies have seen no relationship between the disease and cutting down trees, and some even a negative correlation between deforestation and malaria incidence. An extensive 2016 review by Vittor and colleagues found contradictory evidence, depending on a number of factors, such as the type and scale of deforestation and human demographic changes in forested regions.

As forests disappear entirely, and the tree-fringed mosquito-breeding clearings along with it, malaria may likewise decline.

Despite the equivocal results, researchers are still confident there is a link between malaria and deforestation, albeit complex. A major reason for the discrepancies between studies’ results is the difference in habitat preferences across mosquito species, says infectious disease biologist Gabriel Zorello Laporta at Brazil’s Federal University of ABC in São Paulo. Some “deep forest” species thrive in untouched forested habitats, depending on shade to breed as larvae. The malaria forms they carry tend to decrease with deforestation, says Laporta, who recently wrote commentary in The Lancet on the topic. Other malaria-transmitting mosquitoes require sunny areas to breed, and would increase in abundance if large forest areas are cleared, he says.

The main vector of malaria in the Amazon, *Anopheles darlingi*, appears to thrive in habitats along forest edges. “You’ll find them on the frontier where forest has been relatively recently cleared,” explains Bentley University entomologist Anthony Kiszewski. The insect breeds in warm, shady pools of water that often build up along roads without proper drainage, such as those that cut through rainforests, he says, or puddles behind logs and debris. A study published last year in Scientific Reports found that places with the highest incidence of malaria in the Brazilian Amazon were cleared forest patches between 0.1 and 5 square kilometers in size. These patches contain the
shaded, watery, forest-edge habitat that creates for *A. darlingi* “a good environment for mosquito proliferation,” explains lead author Leonardo Suveges Moriera Chaves, an epidemiologist at the University of São Paulo. Laporta points out that this pattern may not hold up over time: As forests disappear entirely, and the tree-fringed mosquito-breeding clearings along with it, “what you’re going to see is a malaria decrease.”

Chris Drakeley, a coauthor on the macaque study in Malaysia, agrees: Numbers of *P. knowlesi* infections spike in the immediate aftermath of deforestation, but fall several years later as the areas are converted into large-scale oil palm plantations, he says.

In Africa, the main transmitters of malaria are *A. gambiae* mosquitoes, which lay their eggs only in sunlit pools, and have been shown to prefer farmland habitat over shady forests and swamps. Interestingly, a recent statistical analysis by the Washington, DC-based Center for Global Development, a nonprofit focusing on international development, found no correlation between recent forest loss and malaria rates across 17 countries in sub-Saharan Africa.

This was surprising given that previous studies had suggested a positive relationship between the two, explains coauthor Jonah Busch, now at the San Francisco–based Earth Innovation Institute, which researches sustainable development in tropical nations. It’s possible people could have some resistance to malaria already, he speculates, or there could be sufficient prevention strategies in some areas, or fewer people are moving into deforested areas. Kiszewski points to a different reason: Many places in this region were deforested decades ago, giving mosquitoes ample opportunity to establish themselves in cleared areas. “If malaria is already present in a community with mosquito habitat, removing another patch of forest is not going to increase the intensity of transmission much on a population basis,” he writes in an email to The Scientist.

While some researchers are teasing out the nuances in the relationship between malaria and deforestation, others are investigating the transmission of some rare zoonotic diseases that humans have come into contact with.

**Comment**

The discovery that what was primarily diagnosed as *P. malariae* in Borneo was indeed *P. knowlesi* show that a zoonotic plasmodia which, as far as we know, is not able to sustain human to human transmission, is responsible for human malaria in several countries in southeast Asia. With no human reservoir the infections depend on *Anopheles* mosquitoes be present close to the *Macaque* host and humans. The relationship is complex – is it humans moving into the forest, changing habitats of the *Anopheles* or changing behaviour of the Macaques living in closer proximity to humans.

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