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Old diseases return as settlement pushes into the Amazon rainforest

Human activity continues to expand ever further into wild areas, throwing ecology out of balance. But what begins as an environmental issue often evolves into a human problem.

Researchers at UC Santa Barbara investigated how changes in land use may be driving the growth in human yellow fever cases in the Amazon basin. Their analysis, published in Biology Letters, reveals that the growing border between forested and urban areas is causing an alarming uptick in cases.

“Yellow fever is increasingly infecting humans when they are living close to the forest,” said author Kacie Ring, a doctoral student co-advised by Professors Andy MacDonald and Cherie Briggs. “And this is because humans are encroaching into areas where the disease is circulating naturally, disrupting its transmission cycle in the forest."

Diseases like yellow fever had become rare in South America, mostly confined to monkeys in the jungles. The situation was a testament to the remarkable success of public health efforts in the late 19th and early 20th centuries. But the region is now in danger of redeveloping urban transmission cycles, where the disease spreads among the population without the need for a non-human host.

The geography of disease

Ring, MacDonald and junior research specialist Terrell Sipin collected data on the number of human yellow fever cases in districts of Brazil, Peru and Colombia within the Amazon Basin, obtaining records from each country's public health agency. These records stretched back to 2000 for Brazil, 2007 for Colombia and 2016 for Peru.

The authors also culled data on land use from the MapBiomas Project, a large effort to classify land use and land cover. They divided use into categories such as pasture, agriculture, forest and urban areas.

The team compared case rates against three major geographic trends: the average patch size of forest in a given area; forest edge density, or the amount of forest perimeter in a given area; and the amount of interface specifically between forested and urban areas.

In simpler models that only considered the impact of edge density, the team did see a positive relationship with the probability of a yellow fever spillover event taking place. However, this contribution was dwarfed by the effect of forest-urban adjacency in more complex models. It was the proximity of settled areas to the forest that mattered most for predicting yellow fever spillover to humans. A 10% increase in forest–urban adjacency raised the probability of a spillover event by 0.09, or the equivalent of a 150% increase in the number of yellow fever spillover events in a given year. And this borderland is growing by around 13% per year, on average, in the regions included in the study.

When ecology doesn't match epidemiology

Several recent studies have looked at the effect of forest fragmentation on the ecology of yellow fever in the wild. Measures of deforestation correlated with higher case numbers in monkeys and spread of the disease into new regions. In this light, the authors suspected metrics like patch size and edge density would have a significant effect on human cases.

But, in any model that included interactions between human society and the forest, it was this interaction that proved the strongest predictor of human cases. "It was a

little surprising that the ecology wasn't more predictive of the actual transmission to humans," said MacDonald, a professor in UCSB's Bren School of Environmental Science & Management.

"It seems the thing that's causing the disease spillover is that humans are moving closer to the forest edge," Ring said.

The greater the perimeter between the forest and urban areas, the more exposure humans have to the disease. There are often greater infection rates among vectors at the forest's edges, as well. For instance, higher temperatures and more standing water along the forest margins may lead to a greater number of more active mosquitoes.

The return of an old foe

Yellow fever wasn't always rare in the Americas. The neotropics used to have the same sorts of urban transmission cycles as in Western Africa, where the disease is still a significant issue. Along with malaria, yellow fever was behind the failure of the French attempt to complete the Panama Canal. "They were losing workers left and right," MacDonald said. "Over 20,000 workers died." That said, humans didn't know what caused yellow fever or malaria at that time, so they couldn't attribute individual deaths to each disease.

It took new discoveries and massive vector-control initiatives to drive disease rates down to the point where the American enterprise could finally succeed in 1914. These efforts continued in the 1940s and '50s with simultaneous vaccination campaigns and mosquito eradication initiatives that finally freed South America of these urban transmission cycles by the 1940s.

"But a campaign like this would never be executed in the modern day," Ring added. "Widespread use of DDT led to long-term storage in the soil and contamination in drinking water."

Unfortunately, cases have begun rising again, spilling over the expanding border between the forest and urban areas. "We can see the benefits of earlier efforts dwindling," Ring said. "It shows that diseases can come up again if you don't properly maintain the infrastructure of public health and vaccination."

“The concern is that the more we have these spillover events, the more likely it is that we’re going to see these urban transmission cycles reemerging,” MacDonald added.

While the paper doesn’t include data past 2021, data from the World Health Organization shows that case rates have continued to grow. In 2024, human cases of yellow fever were seen mainly across the Amazon region, according to a WHO report. Cases in 2025, however, have been detected mainly in areas outside the Amazon. The 212 cases confirmed before the report published represent a threefold increase compared to the 61 cases in 2024.

Because yellow fever is still relatively rare in the Americas, health agencies don’t have large stockpiles of the vaccine. “So, if cases change suddenly, then we’re unprepared to deal with it,” MacDonald said.

The team will continue to investigate the effects of changing land use on infectious diseases. Ring is currently looking at the interaction between deforestation and tick-borne diseases in Madagascar. Meanwhile, MacDonald plans to investigate how other kinds of land uses affect vector-borne diseases in the Amazon region. For instance, he’s curious how clearing forest for pasture and agricultural production influences the transmission of diseases like malaria, dengue and leishmaniasis.

MacDonald hopes his group’s work will help governments and communities in South America bring development in better accord with human and environmental health. As Ring said, “these emerging infectious diseases are indicators of broader environmental issues.”

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