

# Mapping Global Bushmeat Activities to Improve Zoonotic Spillover Surveillance by Using Geospatial Modeling

*[Announcer] This program is presented by the Centers for Disease Control and Prevention.*

[Sarah Gregory] Hello, I'm Sarah Gregory, and today I'm talking with Dr. Soushieta Jagadesh, a postdoctoral researcher in Zurich, Switzerland. We'll be discussing mapping global bushmeat activities to improve zoonotic spillover surveillance.

Welcome, Dr. Jagadesh.

[Soushieta Jagadesh] Hello, Sarah. Thank you for having me with you today.

[Sarah Gregory] And we're so glad to have you. Your article is about mapping global bush meat activities. What qualifies as bushmeat?

[Soushieta Jagadesh] So bushmeat or wild meat refers to meat from terrestrial wildlife species. So they are species which are primarily hunted for human consumption as a primary source of animal protein, or they are used as a cash-earning commodity.

[Sarah Gregory] What kind of animals are we talking about?

[Soushieta Jagadesh] So they are wild animals from the forests. So they could be anywhere from antelope, smaller mammals (such as badger-like species). They could also be larger animals (larger mammals). And the most commonly sold bushmeat animals include grasscutter rats, bats, monkeys or other primates for example, and herbivores such as antelope, etcetera. And they are primarily hunted only for human consumption, and that's why we termed it 'bushmeat', because that's the meat which comes from the bush or from the forest.

[Sarah Gregory] And what global regions are considered to have bushmeat?

[Soushieta Jagadesh] So bushmeat is a term that is usually restricted to the meat exported from tropical and sub-tropical forests. So that means that these regions...with regions that are covered under the vines of tropical and sub-tropical forests include Africa, the Americas (of course), and Asia.

[Sarah Gregory] Why is North America not included? There is plenty of hunting here—deer, elk, moose, and so on.

[Soushieta Jagadesh] This is certainly a very relevant question. So the hunting in North America is something we call 'game hunting'. So this is hunting which is done primarily for leisure and it is not for sustenance or it's not used as a primary source of animal protein or nor is it a cash-earning commodity. So studies in the early 2000s when they coined the word 'bushmeat', they restricted that to the meat hunted for human consumption in the tropics. And for better or for worse, we chose to stick with that definition in our study. To make sure that we were in the definition of bushmeat, we also excluded trophy hunting in the tropics, because the primary purpose of trophy hunting was not meant for human consumption. And this is not to say that the zoonotic disease risk in North America is negligible, because there is certainly a lot of zoonotic diseases which are transmitted from game hunting, such as tickborne diseases such as Lyme

*Mapping Global Bushmeat Activities to Improve Zoonotic Spillover Surveillance by Using Geospatial Modeling*

disease. But the risk of spillover is much less, because leisure hunting is much less frequent and is mostly seasonal and is not equivalent to bushmeat hunting, which usually happens on a day-to-day basis where you have a constant exposure to wildlife and to the body fluids when butchering these animal carcasses for the preparation of bushmeat.

[Sarah Gregory] What populations use bushmeat as a source of protein, as you mentioned?

[Soushieta Jagadesh] So this is mainly restricted to the rural populations of Central and West Africa and to the Amazonian region of South America. So studies suggest that the rural bushmeat hunters in the Amazon, they consume approximately around 60 kilograms of bushmeat per person per year—so that's around one kilogram per week for an entire year—while those in the Congo Basin who rely exclusively on bushmeat, their protein intake of bushmeat is also quite similar, around 50 kilograms per person per year. And in these regions, especially in West and Central Africa, during the dry season the rivers and lakes dry up. So fishing is no longer an option as a source of animal protein. So their only form of protein comes from the wildlife which is found in their backyard.

[Sarah Gregory] I understand the international markets and restaurants sell it. Why is there a market for this?

[Soushieta Jagadesh] There's two major reasons for the profitability with bushmeat. One is the cheap price. Especially in urban centers, the price of the bushmeat is much cheaper than domestic proteins. So there's a lot more profitability in buying and selling bushmeat protein as an exotic meat. And especially there are populations who really like the gaminess or who enjoy the taste of bushmeat. So that's one of the reasons why there's a high urban demand for bushmeat as well. So this is not just common in Asia, but also in Africa and Latin America. And in Asia (particularly in South China), wild meat is highly sought after for its wild taste, and it is said to bring luck, or it is also known to show affluence in the society for consuming an exotic meat.

Regarding international markets, the demand is especially high for among the expatriate population. And even though a very small percent of product enters the international markets, it's sold at a much higher price in Europe, for example. Even though there are tons of bushmeat seized every year in European airports, there is still quite a bit which seems to get through. And as it's sold at a much higher price, there's always the trade which we always find that there is a constant trade of bushmeat through illegal means by luggage, etcetera.

[Sarah Gregory] Is there a difference in disease spread between populations who depend on bushmeat because they need it as a food source and where it's used for profit in markets and restaurants?

[Soushieta Jagadesh] This is a great question. So in rural regions, a majority of bushmeat hunted as food is used to fulfill the household cooking demands. Now, the bushmeat which is sold for commercial purposes, they serve a much larger population in urban areas, so...and these urban areas that are connected. So we'd expect spillovers in urban cities to spread faster and affect the larger population, as we've seen with the recent outbreak. But this is not always the case, as we've seen with previous outbreaks like the West African Ebola virus epidemic of 2013. This epidemic stemmed from a single zoonotic event which occurred in a tiny village in the tight country border of Liberia, Sierra Leone, and Guinea.

And another problem with spillovers rising from rural regions is that it is far more difficult for surveillance systems to detect an outbreak. So the spread is usually unchecked, and they tend to spread unchecked for a longer amount of time until surveillance systems pick them up, in contrast to urban centers where surveillance and diagnostic systems are usually better at picking up outbreaks by symptomatology.

[Sarah Gregory] You mentioned Ebola. What are some of the health issues associated with consuming bushmeat? What are some of the more well-known spillover diseases?

[Soushieta Jagadesh] Of course, spillover is one of the major health concerns when we talk about bushmeat. But there are also other infections related to bushmeat, which are usually associated with poor hygienic conditions while butchering the meat, so there could be diarrheal diseases as well. And also, lead poisoning is something which is associated with bushmeat because most of the bullets used contain lead to hunt bushmeat, and lead poisoning in communities who consume a large amount of bushmeat is a health issue to not be forgotten. And some of the well-known spillover diseases include, of course, Ebola virus disease, SARS (severe acute respiratory syndrome), and mpox. I think these are quite well-known, especially in the recent years, and they have all been associated with bushmeat consumption.

[Sarah Gregory] Are these pathogens increasing, do you think?

[Soushieta Jagadesh] Oh, yes, most definitely. So over the last couple of decades, we've seen over 70% of the spillover events are zoonotic pathogens, and they have all been associated with wildlife species.

[Sarah Gregory] Why is it increasing? Do we know?

[Soushieta Jagadesh] So there are several reasons for this increase in frequency. And I think the first and foremost, of course, is the expansion of human activities into wildlife habitats, such as deforestation for extensive agriculture or livestock rearing, urbanization, of course bushmeat hunting. And this really increases our exposure to the wildlife that are usually reservoirs of novel pathogens. And the second, of course, is climate change because climate change leads to latitudinal shifts or displacement of wildlife towards human settlements or rural settlements. This is because of drying rivers and these mammals tend to search for food sources elsewhere because their food sources in the forest are drying up.

And the third, of course, is biodiversity loss, and this is due to either deforestation or climate change. And biodiversity loss results in something known as the dilution effect. So this is a hypothesis which is quite debated, but...so basically, what a dilution effect is, is that in areas where there is a variety of different small animal populations, including some populations that are not very efficient in transmitting disease, the risk of transmission of a particular disease from one species to people is usually less, because there's always this one species which acts as a road block to the whole disease transmission process. This particular phenomenon has been established with smaller animal populations like rats. So in South America, hantavirus disease and rats is a very good example of this dilution effect. But this is not a universal phenomenon.

[Sarah Gregory] What are the challenges in preventing these spillovers from bushmeat if it's increasing?

[Soushieta Jagadesh] The major challenge with bushmeat is the fact that it is the only source of protein for months, and it is also the only source of income for many rural villages. So there have been tilapia farming and insects, which had been introduced as an alternate protein source and income source. This failed to be a viable business model because when a hunter hunts bushmeat for his family and village, the excess meat is usually sold at a much higher price to urban city centers. So at the hunter's level, the profitability from bushmeat is much higher because there are no production costs for bushmeat like tilapia farming or livestock raising. And so, it's higher profit. And even if the production costs are elevated by incentives, etcetera, there's no niche in the urban market for the products from of these rural regions (such as livestock), because the urban regions already have their own livestock and tilapia. So that's one of the major reasons why it's hard to ban bushmeat altogether.

[Sarah Gregory] Is this legal—this hunting for bushmeat?

[Soushieta Jagadesh] It depends where it is, in which country. We talk about though in most places of Central and West Africa, bushmeat is legal. There are markets and they actually form a part of the country's economic background, as well. Because most of the bushmeat comes at no production costs, there's a high profitability. And what is seen with banning bushmeat in these regions was that...so there have been bushmeat bans, especially after the Ebola outbreak in West Africa. So there have been bushmeat bans. But the only problem was bushmeat was being traded under the table, and that led to further challenges with underreporting, and it did not really stop the trade once and for all.

[Sarah Gregory] Since we know that spillover can lead to outbreaks (like Ebola) and possibly pandemics, what kinds of assessments were already in place to monitor this?

[Soushieta Jagadesh] So currently there are three major forms of assessments. The first are the surveillance systems, like the Global Health Security Agenda, WHO's Global Outbreak Alert and Response Network, and of course the more famous ProMED-mail. And these are basically global networks of national/international organizations, experts, public health institutions, and in case of ProMED, there are volunteer contributors who monitor and report these disease outbreaks in real time. So this is a passive form of surveillance.

And then we have event-based surveillance, which involves monitoring of media reports—social media tweets, Facebook pages, and also non-traditional sources of potential outbreaks. And finally, we have risk assessment through molecular analysis of potential disease host and reservoirs for novel viruses by either sampling bats in areas at risk...and this was done by the EcoHealth Alliance with their PREDICT program, and this is a more active surveillance system which is currently in place right now.

[Sarah Gregory] Kind of continuing with that thought, what prompted you to create your global bushmeat activities mapping? What was your goal?

[Soushieta Jagadesh] It was mainly because nobody had done it, and it was frustrating for us to model zoonoses and spillover without a synthesized bushmeat variable. And so, other than the modeling aspect, the main goal was to geographically synthesize the distribution of bushmeat activities so that we could use it as an objective, quantitative basis for the allocation of resources for surveillance. So we have the numbers to prove that this is a problem, and it is a problem where surveillance is needed.

*Mapping Global Bushmeat Activities to Improve Zoonotic Spillover Surveillance by Using Geospatial Modeling*

[Sarah Gregory] How did you construct it?

[Soushieta Jagadesh] So we reviewed existing research from the year 2000 to 2002 for geographical locations where bushmeat was either hunted, prepared, or sold. And then we had some environmental and demographic factors which we know influence bushmeat activities, like deforestation, global connectivity between villages, cities and towns, population density...variables like that. And then we modeled them on a presence and absence of bushmeat species using spatial modeling. So we constructed many models. We took the most robust models and then we put them together and we created this map, which was the global distribution of bushmeat activities map. And to make sure that this map actually could predict zoonotic diseases in the future, we validated the map using the map as a variable and established zoonotic disease models. And we used it with two other Ebola models to make sure that the map works.

[Sarah Gregory] What do your findings highlight?

[Soushieta Jagadesh] So our major findings were that one, was that the area calculated from the map that was associated with a high probability of bushmeat activities was equivalent to the surface area of the United Kingdom, which is quite large when we think about it. And the countries which were at the most risk were the countries in West and Central Africa because they had the largest proportion of land area associated with bushmeat activities.

Another very interesting thing about our findings was that there were a lot of areas where bushmeat activity was underreported. So we identified 100 sites in priority in regions of uncertainty for future surveillance for bushmeat activities. The majority of these sites were found in Latin and South America, where currently we find that the bushmeat consumption in urban centers in these regions is on the rise. And the third most important finding of our study was that deforestation was found to be one of the major drivers of bushmeat activities. And I guess this is given because logging roads provide access to deeper forest, meaning that there are more animals to hunt. And also, usually logging trucks can be used to transport the animal carcasses after hunting. So these are the three major findings of our research.

[Sarah Gregory] And who is your mapping available to? Who has access to it?

[Soushieta Jagadesh] So our map is publicly available, so it can be accessed from GitHub repository. There is a link to the repository from the article, and it is also available from our supplementary materials.

[Sarah Gregory] How do you hope this mapping will be used?

[Soushieta Jagadesh] From this modeling perspective, I think this map has a reasonably good resolution, and you can call it an added advantage in modeling and predicting emerging zoonoses on a global and local scale, because we've tested this with Ebola models. And of course, we think that it will really help to strengthen global and local zoonoses surveillance systems, and maybe to a lesser degree, it can also benefit wildlife conservation programs.

[Sarah Gregory] So overall, what are the public health benefits of your modeling and mapping?

[Soushieta Jagadesh] Those modeling and mapping outputs could benefit targeted active surveillance of bushmeat and bushmeat-related zoonotic activities, and this targeted surveillance can be done by the existing local reference laboratories, which have been established by the

*Mapping Global Bushmeat Activities to Improve Zoonotic Spillover Surveillance by Using Geospatial Modeling*

World Organisation for Animal Health (WOAH). And it can also be used by global outbreak preparedness initiatives, like the Global Health Security Agenda.

[Sarah Gregory] What kinds of future investigations need to be done on this topic?

[Soushieta Jagadesh] This is something we kind of discussed earlier. The most important is just understand the need for the urban demand for bushmeat. So a lot of anthropological studies need to be done to find out why is there this urban demand, and is there a way that it can be decreased and how can it be decreased? Because there's been several bans that have been ineffective in curbing the selling and the demand for bushmeat. And they really tend to push the consumers and the sellers for under-the-table trade, and this has led to more challenges in the monitoring of spillovers and also bushmeat trade.

[Sarah Gregory] Where do you work? What's your job and specialty area and what do you like most about it?

[Soushieta Jagadesh] So I work at the health geography and policy group at ETH in Zurich, and my job is an infectious disease epidemiologist who specializes in spatial modeling and emerging infectious diseases. And what I like most about it is probably everything. Especially in the current environment, there is a need for integrated research when it comes to prevention and control of emerging infections. So when I started off, I started off as a junior doctor in clinical infectious diseases and travel medicine. But with academic research, I get to collaborate with not just fellow epidemiologists, but also with veterinarians, molecular biologists, policy makers, anthropologists. So I think it is a great environment to work in at the present with the outbreaks (the up-and-coming outbreaks).

[Sarah Gregory] And there seems to be plenty of them. Do you worry about the future and all this spillover?

[Soushieta Jagadesh] Well, I don't worry about the spillovers because I know that they are inevitable. But I worry about the spillovers that turn into outbreaks. So I'm concerned that we are more reactive in response to outbreaks than prevention. The factors driving these spillovers have been well established, but yet we wait for these outbreaks to happen. And I'm also worried that the political world preventing these outbreaks is restricted more to the research and development of therapeutic measures, which of course is very important. But there's also a need for steps to be taken for combating climate change, for establishing local surveillance assistance at risk areas, for the crosses of such as bushmeat trade, deforestation, etcetera. And I think these small changes are equally and potentially even more important at current times.

[Sarah Gregory] Well, thank you so much for taking the time out of your very interesting life to talk with me today, Dr. Jagadesh.

[Soushieta Jagadesh] Thank you for having me.

[Sarah Gregory] And thanks for joining me out there. You can read the April 2023 article, *Mapping Global Bushmeat Activities to Improve Zoonotic Spillover Surveillance by Using Geospatial Modeling*, online at [cdc.gov/eid](https://www.cdc.gov/eid).

I'm Sarah Gregory for *Emerging Infectious Diseases*.

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