Micro–Global Positioning Systems for Identifying Nightly Opportunities for Marburg Virus Spillover to Humans by Egyptian Rousette Bats

[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. Brian Amman, a disease ecologist at CDC in Atlanta. We'll be discussing the risk of Marburg virus spillover from Egyptian rousette bats.

Welcome, Dr. Amman.

[Brian Amman] Thank you. Thanks for having me.

[Sarah Gregory] Marburg virus is not one that we hear a whole lot about, but what is it?

[Brian Amman] Marburg virus is a zoonotically transmitted virus that belongs to the family Filoviridae, and it is a negative-sense RNA virus that produces severe disease in humans but also is transmitted from animals to humans and does not produce a disease or severe disease in its natural reservoir.

[Sarah Gregory] This disease is caused by both Marburg and Ravn orthomarburgviruses. How are these viruses related, and do they both cause the same disease?

[Brian Amman] Marburg virus disease is caused by both Marburg virus and Ravn virus. They're similar with respect to their genetic makeup. They're about 20% different from one another, which makes them belong to the same genus (which is *Marburgvirus* genus). They do cause the same Marburg virus disease because they are so similar.

[Sarah Gregory] How and where was Marburg first discovered?

[Brian Amman] Marburg virus was first discovered after a shipment of non-human primates or monkeys from Africa went to a place in Germany and another place in the former Yugoslavia, and these institutions were using monkey kidneys to create cell lines for research and pharmaceuticals. Well, it turns out that these monkeys were in fact infected with Marburg virus disease. And this was back in 1967, and the people that were performing the necropsies and harvesting the cells became infected with this unknown disease that later became called Marburg virus because of Marburg, Germany.

[Sarah Gregory] Do we know what happened to those people?

[Brian Amman] Yes. there were several cases and several deaths. They exhibited the typical symptoms of Marburg virus disease, and it was through those infections in that small outbreak that this new virus was discovered. It was the first virus in the family Filoviridae to be discovered.

[Sarah Gregory] So now what parts of the world is it usually found in?

[Brian Amman] Marburg virus—and both Marburg virus and Ravn virus—are typically found in sub-Saharan Africa. There have been outbreaks of Marburg virus disease in other places, but typically they involve some sort of travel to sub-Saharan Africa. There have been cases in South Africa that the origination of the travel was from Zimbabwe—so again, sub-Saharan Africa.

There has been a case identified in the Netherlands that was originally...the infection occurred in Uganda, another one in the United States where the infection occurred in Uganda. So most of the outbreaks' origins occur in the sub-Saharan African tropical zone.

[Sarah Gregory] There then was no initial spread in Europe from the primates in the 60s in Germany and the former Yugoslavia?

[Brian Amman] Yes, there was. There were some original workers that were identified or that became ill, and some healthcare workers got sick from them, and that's usually how Marburg virus is transmitted. It's typically a spillover from a natural reservoir or an infected non-reservoir animal, and then the primary care given to the sick patients result in human-to-human transmission, and those can result in some rather large outbreaks.

[Sarah Gregory] But it didn't cause a general spread throughout Europe?

[Brian Amman] No, not in Europe. In the European or the original outbreak in Germany and Yugoslavia, the pathogen was identified as being a human-to-human transmission type of pathogen and very quickly they increased the barrier nursing practices that stopped the outbreak. But it was stopped quickly because of barrier nursing. In Africa, that's typically not the case because certain items of personal protective equipment like latex gloves and face masks and things that would protect from droplets are not available, and these outbreaks can get big very quickly there because that very basic PPE or personal protective equipment is not available to healthcare workers in those areas.

[Sarah Gregory] Marburg virus causes hemorrhagic fever just like Ebola does. How is it actually different from Ebola?

[Brian Amman] Marburg virus and Ebola virus are in the same family (Filoviridae), but they differ by as much as 50%. So if you looked at it sort of in a general sense, you could look at Marburg virus and Ravn virus as being siblings (brother/sister, brother/brother), whereas Marburg virus and all of the species of Ebola virus would be more like cousins. So there is a separation in genetic identity between those two, but they all belong in the same viral family. They all produce very similar courses of disease when the human is infected.

[Sarah Gregory] Egyptian rousette bats are apparently the natural reservoir for this virus. Tell us about this bat.

[Brian Amman] Okay. Well, Egyptian rousette bats, their scientific name is *aegyptiacus*, and they have been suspected as being a reservoir as early as the 2000s. And then in 2007 when our branch responded to an outbreak in Uganda after some miners became sick with Marburg virus disease, we were able to be on site very quickly, we captured these bats and identified them as the official reservoir, which means we found active infection in the bats, we were able to isolate the virus from the bats, and all the aspects of identifying a reservoir were identified time and time again, both in the mine and in another outbreak that occurred very close to that mine in southwestern Uganda. Now, the thing about these bats is that they belong to the family Pteropodidae, which is essentially a very diverse family of fruit-eating bats, but what makes them different is they really like to colonize areas, specifically caves or mines or dark, dark places where they don't have a lot of human contact and they can grow or the colonies can grow to as many as 100,000 bats or more. In fact, the mine where we first identified Marburg virus in these bats, the colony there was over 100,000 strong. They eat fruit like I mentioned, they fly

long distances to get to these foraging sites, they prefer really sweet fruits (bananas, mangos, papaya, guava), they'll eat nectar.

And so, they like to roam around looking for these types of fruits to eat. They generally breed twice a year in the tropical zones of sub-Saharan Africa, but when you get into the farther northern climates like Israel or far south like South Africa, that drops generally to one time per year. So these colonies can grow pretty fast with the double or the twice a year breeding cycles, but they are also very typical of most bats where they have one pup per breeding cycle. Sometimes they'll have twins, but that's pretty rare. One of the unique things about this particular bat in the family Pteropodidae is that they do use a group form of echolocation, whereas the rest of the members of the family Pteropodidae do not. And this is similar to other insectivorous bats that primarily rely on echolocation to navigate. The difference with rousette is that they'll use echolocation to get out of their dark cave, but then once they're out, they primarily rely on good eyesight to find what they need and smell the fruits that are available to them.

[Sarah Gregory] Bats are so fascinating. I've done some other podcasts on bats and one of the unique features of them is apparently they can have various diseases, but not manifest symptoms. Is this true of these rosette bats and Marburg?

[Brian Amman] Yes, that is true. They are not asymptomatic. There is some mild pathology that we have discovered in these bats. But in terms of a typical course of disease, these bats do not suffer overt signs of morbidity or illness like, say, a non-human primate or a human would. So typically, we've done BSL-4 laboratory experimentally infecting these bats with Marburg and Ravn virus, and we don't really see a rise in temperature, they don't lose any weight, they don't get lethargic. They just sort motor right on through it, like someone would basically with a cold. It's not a very debilitating disease in these bats. And other bat species, you know, are typical, but most of these reservoir species of any type of zoonotic reservoir will suffer more over a limited disease, if you will, because if you look at it, if the virus really knocks down their host, then they're not very efficient at transmitting the virus. Especially if it kills their host, the virus line won't be continued. So they typically are less affected by infections than a non-host would be.

[Sarah Gregory] Can other bat species or animals carry Marburg?

[Brian Amman] Yes, but not in the sense of the way a natural reservoir would. We have captured bats that were not *Rousettus aegyptiacus* that have tested positive for Marburg virus disease and other researchers have done so as well (two of them that were insectivorous bats) and we identified an active infection or at least viral RNA in their systems, but they were unable to either shed the virus or transmit the virus which made them a non-host or what we call a 'dead end' host. Other animals can become infected with Marburg virus (like non-human primates) and become very sick, and through the human interacting with that particular sick animal, then they can become infected. So we don't consider that necessarily a natural reservoir. What typically happens in sub-Saharan Africa or in the tropics in Africa is that a non-human primate will encounter this virus and become very sick, and that usually makes them fairly easy to capture because they're on the ground, they're slow and they don't feel well, and then the human that captures that animal or a duiker or any kind of other animal that would become infected and ill with this is then taken to market where they're processed or butchered, and through that process of handling that animal, the human becomes sick. But typically, that occurs through Ebola virus outbreaks more so than Marburg virus. Usually Marburg, or I should say not usually, but about

half of the outbreaks that have occurred with Marburg virus, there has been a link to human encroachment on bat habitat or some sort of exposure to bat activity or habitat.

[Sarah Gregory] Okay. So clarify for us how exactly people do get infected with this Marburg virus. You mentioned it can spread from people to people. Is it initially eating the animal so it's ingestion, or is it droplets? What is infecting the people?

[Brian Amman] With the exception of the first Marburg virus outbreak in Germany and Yugoslavia—we know that was direct contact with infected monkeys which are not the natural reservoir—just under half of the outbreaks that have occurred, typically there is a traveler that has gone to visit a cave or, you know, been in an area where there's a lot of bats. So we suspect what occurred there was droplets or contact with Marburg virus deposited in the guano of the bats and there was hand to mouth, and that usually results in the initial spillover event. And then from there, what happens is that individual could become sick, they go to a healthcare facility, and if there's not really good barrier nursing practices at that facility, then the healthcare worker can then become infected. Or family members, even, that take care of the sick individual—let's say they just go home—these people take care of the sick person and usually there's vomiting and a lot of bodily fluids involved in Marburg virus disease that can then be very infectious, and whoever is helping that, if they're not protected, they become sick and then it just builds off of that.

[Sarah Gregory] Have there been large outbreaks of Marburg like we've seen with Ebola?

[Brian Amman] There have been large outbreaks, not nearly as big as the Ebola outbreak in 2014 in West Africa, but still fairly large. There was one in Angola in 2005 that resulted in about 200...I want to say 250 human cases that had a case fatality ratio of 90%. So there were around 227 deaths out of the 250 human cases, and that was pretty severe. And in 1998 to 2000, in sort of an extended Marburg virus disease outbreak in Durba, DRC, there was 154 cases, around 128 deaths...something like an 83% case fatality ratio. And those are the two largest. Normally what we see are smaller outbreaks, and a lot of times it's one or two, or sometimes it's just one—that person walked into the wrong place. But that all depends on where the outbreak has occurred. In places that have a good surveillance system set up, usually they can identify it very quickly and all of the appropriate PPE is brought in to help contain in the hospital setting.

[Sarah Gregory] You mentioned vomiting, diarrhea. What are all the symptoms of Marburg virus disease?

[Brian Amman] Well, the symptoms of Marburg virus disease typically start out very similar to symptoms matching those of flu or malaria, and it can really cause problems because it makes it hard to diagnose just on a general sense. Someone would come in and say I don't feel well, I've got a fever, a headache...sort of your general flu-like symptoms, and that causes problems because then they are sent to a care facility without the necessary caution that one would take for something like Marburg virus disease. So usually anywhere from two to 21 days after the initial spillover or the exposure, these symptoms develop and they are typically fast—fever, chills, headache...sort of body aches, that kind of thing. But after about five days, you start to develop more identifiable symptoms like a body rash, nausea, vomiting, chest pains, sore throat, and they get more severe (a lot of diarrhea), and they become increasingly worse and even in some cases, I think it's roughly half or a little bit less, you get this hemorrhagic involvement where you have blood vessels being damaged, so there's a lot of bleeding. And that one is usually a very

identifiable symptom that puts them right into hemorrhagic fever virus category. And then, of course, everybody is all alert once that starts to happen.

[Sarah Gregory] Since it is a virus, how is it treated? There won't be antibiotics. What's done for these people?

[Brian Amman] Usually, it's just supportive care. It's trying to maintain the electrolyte balance in the body, trying to maintain hydration, keeping them comfortable. There really are no treatments like antivirals. I think some have been tried, especially with the Ebola viruses, but with Marburg I don't believe there's been any very successful antiviral treatments to this point.

[Sarah Gregory] Is there a vaccine for it? Or one that’s in the development stage?

[Brian Amman] There are vaccines in the developmental stage that are not approved for human use yet that I'm aware of. So no, there's really nothing out there right now that you can give to the population, not for Marburg virus disease anyway.

[Sarah Gregory] Overall, how deadly is it? You mentioned one outbreak where most of the people died. Is that the norm?

[Brian Amman] There's a wide range. And again, it all depends on where it occurs and how ready or alerted the healthcare system is to the outbreak. And, you know, a lot of times when it's an area that hasn't seen Marburg virus outbreaks before, the case fatality ratio and the cases can get quite big. But I guess the range that we've seen...the typical range is anywhere from 23 to 90%. But it also, if you look at every or the history of the Marburg virus and the outbreaks, it goes from zero to 100. Again, it all depends on the number of people and how severe or quickly it is responded to. The average or the normal range is anywhere from 23 to 90, so it can be quite lethal.

[Sarah Gregory] In your article, you used micro–global positioning systems to track the nightly movements of these rousette bats in Uganda. Explain to us what micro–global positioning systems are.

[Brian Amman] I guess the layman's term for micro-global positioning is just GPS, and it's kind of the same thing that you have in your car or in your phone. It just uses a satellite to identify where you are on the planet at that particular time. Now, micro-GPS is just a really small GPS unit that's lightweight enough—and in our case, it's seven grams or less—that we can attach to the back of these bats. So it's essentially just a small GPS tracker that we put on the bats to look to see where they go at night. We use typically a pre-set timing interval, and in the study that you're referring to, we had these GPS units come on at seven p.m. at night and turn off at five a.m. in the morning, and that's because we wanted to conserve the battery life. Now, these units that we use are self-contained, so they have a limited amount of battery and they are wireless, so that any data points that they collect while they are outside of the cave will be wirelessly downloaded to a base station that we set up at either end of the cave so that when the bats come back home, the data goes straight to the base station.

Now, while the bats are out in between the hours of seven and five, we have these units basically search for a satellite and mark a location every five minutes—so every five minutes, this thing turns on, finds a satellite and says, "okay, this is where this bat is at this point in time, and then it saves it until it gets back to the base station, where it is then downloaded onto the base station,

and then the next morning I can go up to the cave, get the base station, and get the data off that base station".

[Sarah Gregory] What were you looking for?

[Brian Amman] Essentially, we wanted to see where the bats were going at night, and this is where the GPS story kind of comes to, I guess, full circle. Early on when we started working with these bats, we identified them as the natural reservoir, we knew that they...you know, were probably going to homes because in our work in Uganda and all across Africa, we...you know, a lot of people have a mango tree or a guava tree or a papaya tree right there in their front yard that they routinely go out, pick, and use for their own consumption, as well as bananas (lots of crops of bananas). So we knew that these bats would not just simply overlook them because they're in someone's front yard. They primarily operate at night, and most exclusively operate at night, so there's not going to be a lot of activity to scare them away, and because they can fly they can come in and grab what they need and get out of there very quickly.

So we just had this feeling that they were using these crops that people were also sharing with them, and we wanted to figure out a way that we could show this. But first of all, what we wanted to really do was establish that these bats could actually shed virus onto these fruits, and this takes us all the way back to 2011 when we captured bats and brought them back to the CDC to form a breeding colony so that we could experiment and learn just exactly how this virus works in these bats. So we took these CDC-born and bred bats into the BSL-4, we infected them with Marburg virus that we isolated from a bat from our initial outbreak response in the mine in Uganda, and we tracked how the virus progressed through the bat. We tracked which tissues it infected first; second, how long it stayed infectious; and more importantly, where the virus was shed. And through those experiments, we learned that these bats shed virus in their saliva, which is how they give it to one another through biting and confrontation. It's shed through urine and feces as well, which also indicates how these bats can give it to one another. And more importantly, how these bats can give it to humans when they have reported no physical contact with a bat, but they were in bat habitats. So they probably got a droplet in their eye or got some on their hand and didn't wash their hand properly, and then became infected that way.

So now that we know that these bats shed virus in saliva and urine and feces, we wanted to establish how long that virus could live outside of the bat on something like mango and banana. So we then set up an experiment where we put live Marburg virus on mango and banana, which are commonly cultivated fruits in Uganda, and we learned through this experiment that this virus can basically stay live and infectious up to and possibly beyond six hours. So now that we have that established, we have the bat that can take the virus from the population where it's overnighting out to a remote location, which we suspect could be a tree in someone's front yard. The bats themselves like to test bite fruit, and if it's not quite ripe enough, they'll drop the fruit on the ground or leave it in the tree with a bite in it. And if the human being that comes along the next morning picks it up and says, "oh this is a good mango, I'm going to take it in and eat it", and doesn't wash it properly, then they can be infected this way.

Now keep in mind, just under half of all Marburg virus outbreaks are linked to human behavior in and around bat habitats. There's still another path of all these outbreaks that have occurred that have really no link to bat habitats at all, and this was one of the things that we're trying to establish is this could potentially be how these people were getting infected without being in the cave or in the mine. So now that we know these bats can fly pretty long distances to get to these

fruit trees, can we establish or really say that this does, in fact, happen. And the only way that we can do that is either trap around the trees, which is kind of a very undetermined way to identify that they do use them from a particular cave, or we can mark the bats in this cave with GPS units, track where they go, get the data, and then look, take the data and put it into Google Earth and see exactly where they go.

So that's pretty much what we did. We put...in February and August of 2022, we put 100 units on 100 bats, tracked where they went. I looked at the data, and sure enough, as we mention in the paper, that actually a lot of bats went to areas like this. But one in particular that really piqued our interest, it went straight from the cave to a house in a village nearby and spent a lot of time at that house. And that was interesting just seeing this data, you know, looking at Google Earth and realizing just how much time it spent. It left the house, so if it were to eat a piece of fruit and drop it on the ground, there was at least four hours where a human could walk outside during the day, pick that piece of fruit up and eat it and become infected, were this bat infected with Marburg virus. So what we did, we took those GPS coordinates, we got it in our GPS and we drove to the place that was identified by these coordinates, and when we pulled up, sure enough there was a mango tree in the front yard, avocado, papaya...it was surrounded bananas, there were children playing in the front yard and there was even a small, young pig rooting under the mango tree—all potential for spillover, right here. So that sort of put the cap on this whole question of ours. Can they take Marburg virus to humans? Does it necessarily have the humans going to them to become infected? And the answer to that is definitely yes.

[Sarah Gregory] What's the size of these bats?

[Brian Amman] They typically have a wingspan roughly one and a half feet to two feet on the larger end. Some of the larger males can get close to 190 or 200 grams, but typically the average adult is around 130 to 140 grams. So they're not terribly huge, but they do look large when their wings are spread.

[Sarah Gregory] What's the process of attaching these GPS systems to the bats?

[Brian Amman] First of all, you have to catch them. So we go to the cave, we put all of our PPE on, and we capture the bats and then we take them...we'll put them in cloth bags (like pillowcases) so they're comfortable, and we'll put them in... you know, a few to each bag. We take them back to a processing area where we can do it safely. And it takes two people to do this process, and one person...all of this is done with PPE on (PAPRs and gowns). But one person is wearing some Kevlar gloves so that they can handle the bat and if they bite, they won't go through the glove. And one person holds the bat, and another person will take samples. We take an oral swab. We take a blood sample from a winged vein so that it's not a lethal sample at all, it's just sort of like taking a glucose blood sample from a child—you give them a little poke with a lancet, collect the blood, then, you know, staunch the bleeding with styptic gel. And then, of course, we take a rectal sample. And all those samples are analyzed for viruses.

And then once that's done, we turn the bat over and we shave a small patch of hair off its back, right between the shoulder blades, where we then take veterinary surgical glue—it's almost like veterinary super glue—and we put a little spot of that on their back and a little spot on the GPS unit and then place the GPS unit right on the back between the shoulder blades. From there, the bat is taken to sort of a screenhouse where we put it in there so it can fly around, we can make sure that the bat can fly unencumbered, and to make sure that the GPS unit doesn't fall off or it

get pulled off right away. And then, after five or 10 minutes, we see everything's good, we'll open the thing and let the bat fly back to the cave. And generally, they'll fly straight back to the cave, even in the daylight.

[Sarah Gregory] What happens to these little GPS systems on their backs eventually? Do they just fall off finally or do you have to go back and take them off or are they there forever?

[Brian Amman] We chose the glue specifically because it says it's good for about five days. I mean, we're just assuming because we don't get any more data points off of the bats. But typically, if any are read starting at about day four, we start to see the data fall off day five, and we think what's happening is that the glue is sort of decomposing or degrading and the unit will eventually fall off. And we do this on purpose because we don't want these bats to have to carry these GPS units around for a really long time. We do have some plans to look at longer term foraging, where we could potentially keep these units on the bats for months at a time (two to three months) just to see what they do over long periods of time, but that's further on down the line and we'll probably end up using a different attachment method at that point. But for this study, it was just the surgical glue that degrades, and the unit falls off at about five days.

[Sarah Gregory] So while you had these bats, you did some viral testing, is that right?

[Brian Amman] Yes. We wanted to establish, you know, first of all, that the virus is still circulating in this cave, and the cave that we were working out of is in Queen Elizabeth National Park. It's called Python Cave, and it is a tourist attraction. And what got us there to begin with was a tourist from the Netherlands became infected and took the virus all the way back to the Netherlands before she was identified as having Marburg virus. And then a woman from Colorado in the United States was identified retrospectively, who had also visited that cave several months before the Netherlands tour (so the Dutch tour). So we've been working out of this cave because it's an established and protected population, it's stable, and we can go there, work and do longitudinal studies at that time. So what we wanted to do with this...we know the virus is there. It's going to be there all the time because the bats are there.

But we wanted current data that, yes, the virus is still there. So we tested them. We took blood samples, and we took oral swabs and fecal samples. Now, we even did some destructive sampling just to make sure we identified it, because you can miss virus when you do non-destructive sampling. But we did establish that Marburg virus is still circulating in that cave. And we tested for other viruses as well. It's not just Marburg virus. But those results are pending and probably going to be up in another study here real soon.

[Sarah Gregory] Do they still allow people to go into this cave?

[Brian Amman] They don't. Part of our work out there through these longitudinal studies was to help the Uganda Wildlife Authority design a safe viewing platform. Now, one of the reasons people go into this cave is to see the very large pythons there that can, you know, get very, very large, and they're very interesting and neat to see. But it's extremely dangerous to go anywhere near that cave—one, for Marburg virus reasons, but another is that the cave is full of black forest cobras as well, and they're extremely dangerous and aggressive snakes. So we came up with a design that would keep the bats from roosting on this viewing platform, but still allow tourists to open some shutters to keep the windows clean and look through glass windows so that they can actually look in and see the population of bats and see the snakes when they're sort of out in the

front. It's not as, I guess, adventurous as going into the cave, but it's a whole lot safer for humans in general.

[Sarah Gregory] What are the most important public health implications of your findings?

[Brian Amman] The most important public health implication of our findings is that these bats can take Marburg virus to people that aren't necessarily encroaching on bat habitat. And probably one of the most important recommendations that we can develop from these findings is that you shouldn't eat fruit that has been bitten or look like it has been bitten, and you shouldn't let your domestic animals—your, you know, dogs, cats, pigs, goats, any of that kind of thing—eat these fruits that have been bitten on. And then it's probably a good idea, if not definitely a good idea, to wash all the fruit that you collect out of these trees. I would like to reiterate that we did also determine that virus can be shed in urine and feces, and it's quite possible that while the bats are in the trees, you have these events happening that land on the fruit and contaminate it that way. So the biggest issue is that we've identified these places where these bats go, we can see how far they go. And if you're within range of some of these things, you need to be extra careful when harvesting your fruit. And our intentions are to work with the Uganda Wildlife Authority and the Uganda Ministry of Health to publish a public health risk map of that area so that if you fall within this range, you need to be extra careful when harvesting your fruits.

[Sarah Gregory] I know Nipah virus is carried by bats urinating also on food crops. Is washing sufficient?

[Brian Amman] Typically, yes. Detergents are... you know, this is one of the recommendations that we used during the outbreak for first responders was make sure you wash your hands with soap and water. The detergent is hard on the virus. It can wash it off, degrade it, destroy it, whatever you want to do with that. But I mean, that's just a generally good practice to be in anyway, and I understand that some of these places don't really have, you know, running water, access to good soaps and things of that nature. But simply rinsing and the physical act of moving hands over the fruit would be enough to possibly remove the virus. So we're going to recommend that, and whether or not it is put into practice is a totally different thing, but at least we can say, "this is what you should do".

[Sarah Gregory] It seems to me there probably were a lot of challenges while you conducted this study. What do you think was the most challenging aspect?

[Brian Amman] With field work, there's always a lot of challenges—getting there, making sure everybody's safe, the PPE. But I want to say probably the most challenging thing with something like this is once you've identified a reservoir—you've identified the fact that it can take virus to people, it doesn't necessarily have to just sit there and let people come to it—the hardest part is convincing people that killing the reservoir is not the way to go. And one of the first things that happened to us in responding to the 2007 outbreak in the mine was that the miners took it upon themselves to destroy that entire population of over 100,000 bats in that mine. And they thought they were doing right—the bat carries the virus, we need to get rid of the bats so we can go back into the mine and work, you know. And we advised against it at the time because we didn't really know what would happen.

Well, that population over time repopulated the mine. There was another outbreak in the area. We went back to that area...and this is a paper that we published in EID—you can look it up, resurgence of Marburg in Kitaka mine, I want to say 2014 or something. But when we went back

to the mine, we discovered that the rate of active infection went from around 5% in the population in 2007 to, at this time in 2012, over 13%. So not only did the bats come back, there was more Marburg virus there. So it made the thing worse. And that is just one aspect of not destroying the natural reservoir that we try to get across to everyone involved, even in, you know, with the public. Just leave the bats alone, stay away from the bats, and generally you'll be safe.

The other thing is that these bats are very ecologically important to the ecosystem. They're seed dispersers, pollinators, and they play an important role in just the natural food chain (the predator/prey food chain). And it's important to not destroy these bats, but just keep your hands off them and keep away from them. And that's typically the hardest thing to get across, you know. Even in the United States, we try to say, "look, leave things alone. Just stay out of the habitat". And that's...I would say that's easily the most challenging thing with some of this field work.

[Sarah Gregory] Tell us about what you do at CDC and what you enjoy most about it.

[Brian Amman] I'm a disease ecologist and I guess my first order of business is outbreak response. And you know, while I have worked on the human side of things, I typically come in after the human side of things is under control, and then I look for the animal reservoir. I try to determine how the virus went from the animal reservoir (if it's even known) to the human population. A lot of times, we don't know what the reservoir is (Ebola is a good example of that). So we've spent a lot of time in the field catching bats, looking for Ebola virus in bats, and we've yet to find it to identify a reservoir. Unlike Marburg virus, we went out, found Marburg virus, and now we can establish ways for people to keep safe because we know what the reservoir is. Ebola, you know, all we can say is just don't touch bats in general.

So once we've done the outbreak work and met our primary responsibility, then I'll bring the data back and we start looking for things like patterns or, you know, especially if we have a reservoir, I can then start studying all the dynamics and the relationship between the reservoir and the virus and the reservoir, virus, and human, and figure out ways that this virus is getting out of the reservoir and into the human so that we can come out with public health messages to say, "look, stop that behavior" or "try not to do this" or "stay away from that area", that kind of thing. So it's generally taking the whole ecological picture of the natural reservoir and the virus and the human being and looking for things to keep people safe. To put it in a nutshell, that's what I do.

[Sarah Gregory] Well, it sounds like a really fascinating job to me.

What is the one disease you would choose to end and why?

[Brian Amman] I'd have to say cancer, you know, non-viral, because it's just...it's so indiscriminate and it can affect anyone, anytime, without or with risky behavior. It's just a bad one. But if I had to pick one that was caused by a virus, I would say like the respiratory viruses—flu, SARS, RSV—those kinds of things because they're so easily transmitted, and they have such an impact on the human population. I mean, they just are devastating.

[Sarah Gregory] As we have all learned in the last few years.

Thank you so much for taking the time to talk with me today.

[Brian Amman] It has been my pleasure. Thank you for having me.

[Sarah Gregory] And thanks for joining me out there. You can read the November 2023 article, Micro–Global Positioning Systems for Identifying Nightly Opportunities for Marburg Virus Spillover to Humans by Egyptian Rousette Bats, online at cdc.gov/eid.

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

[Announcer] For the most accurate health information, visit cdc.gov or call 1-800-CDC-INFO.