

PLOS Science Wednesday: Hi Reddit, we're Raina and Olivier and we conducted a review assessing the spillover dynamics of four common viruses with bat reservoirs and outlined a research agenda based on our findings – Ask Us Anything!

PLOSScienceWednesday¹ and r/Science AMAs¹

¹Affiliation not available

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Abstract

Hi Reddit, My name is Raina Plowright and I am an Assistant Professor of Epidemiology at Montana State University. I use field, lab and modeling approaches to understand how pathogens persist in wildlife populations (especially bats) and spill over to humans. And my name is Olivier Restif and I'm a Lecturer in Epidemiology at the University of Cambridge. I use mathematical models to track the spread of microbes within their hosts and across populations. In particular, I'm trying to find out how the ecology of African bats may contribute to their ability to spread viruses. We recently published a paper titled "Transmission or within-host processes driving pulses of infection in reservoir hosts" in PLOS Neglected Tropical Diseases. We examine the dynamics of emerging bat infections within their reservoir host populations. We argue that understanding the mechanisms that drive pulses of excretion of viruses such as Hendra, Nipah, Ebola and Marburg viruses, is essential to predict or manage spillover risk. We outline an ambitious multidisciplinary research agenda that would allow better management or even prevention of spillover. We will be answering your questions at 1pm ET (10 am PT) – Ask Us Anything! You can follow Raina on Twitter at @rainamontana and Olivier on @BugsWormsNBats.

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PLOSSCIENCEWEDNESDAY [R/SCIENCE](#)

Hi Reddit,

My name is [Raina Plowright](#) and I am an Assistant Professor of Epidemiology at Montana State University. I use field, lab and modeling approaches to understand how pathogens persist in wildlife populations (especially bats) and spill over to humans. And my name is [Olivier Restif](#) and I'm a Lecturer in Epidemiology at the University of Cambridge. I use mathematical models to track the spread of microbes within their hosts and across populations. In particular, I'm trying to find out how the ecology of African bats may contribute to their ability to spread viruses.

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Wednesday: Hi Reddit, we're
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Thanks for spending time with us today.

Could you briefly describe bat vs human immunology and why bats are such capable hosts?

[PHealthy](#)

[Raina] There is a growing understanding that bats may have an unusual immune system that allows them to carry viruses without experiencing disease. Their special immune responses may be a consequence of adaptations for flight. Bats must increase their metabolic rate up to 16 fold to fly (compared to birds who increase metabolic rate two fold). To deal with high metabolic rates bats must deal with the byproducts of oxidative metabolism. Recent work suggests that they evolved mechanisms to deal with oxidative stress that also happen to help them deal with intracellular pathogens, such as viruses. Another hypothesis that we described recently is the "flight as fever" hypothesis -- that bats increase their body temperature during daily flight, and this may drive selection for lower virulence pathogens (fever is a mechanism the body uses to fight pathogens).

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I saw you recommend the book *Spillover* in another comment, any other suggested reading? Either popular writing or interesting/groundbreaking scientific papers welcome! I've done a fair bit of reading in this area (including *Spillover*) but I'm always looking for more.

[TelemarketingEnigma](#)

[Raina] Peter Piot's biography "No time to lose: a life in pursuit of deadly viruses" is a fascinating account of early exploration into the ecology and epidemiology of Ebola and HIV and other infections. I could not put it down!

Are either of you afraid of the animals/infections you face everyday? How do you manage that fear? - For the longest time I wanted to be a field biologist-ethologist but I was afraid of the dangers of the field, so I decided to stay in molecular biology/neuroscience arena in a wet lab.

[saraprinss](#)

[Raina] I think it is important to put the danger in perspective. We are all full of microbes, and the air we breathe is full of microbes from many other species. Every time we pat our dog or cat we are exposed to microbes. But very few of these microbes cross species barriers and cause disease. Probably because we have very effective immune barriers to pathogens. There is also growing evidence that early exposure to pathogens may be beneficial. But I do agree, the more you know about the scary but rare pathogens, the more it clouds our perception of the real risk of infection.

Besides humans, which other species suffer diseases that have bats as reservoirs? Besides rabies, is there any other disease that can affect multiple species, that has a similar transmission mechanism?

[MarsNirgal](#)

[Olivier] There are a few known examples, and probably many unknown cases. Nipah virus in South-East Asia is transmitted from bats to pigs, and the closely related Hendra virus in Australia infects horses. Transmission is thought to occur when bat urine contaminates drinking water for animals in fields. Hendra is lethal to horses, while Nipah causes less severe disease in pigs. MERS coronavirus, which is probably spread by Rousettus bats, infects camels. Ebola virus has caused deadly outbreaks in gorillas, and is seen as a major threat to endangered apes in Africa.

Thanks for doing this AMA. My question is: how big a role does bushmeat play in transmission to humans?

[chiropter](#)

[Olivier] This question received a lot of attention during the latest Ebola outbreak in West Africa, where the consumption of bat bushmeat was quite common, and bans were rapidly put in place. However, the evidence is still scarce. Before the outbreak, my PhD student Alexandra Kamins carried out a detailed survey of bat bushmeat in Ghana, which unravelled a major trade business across the country. We think that consumption of bat bushmeat, which is usually thoroughly cooked, poses limited risk of infection, unlike hunting and butchering activities. However, we didn't find any evidence of exposure to bat viruses in hunters in Ghana.

It's a delight to read this AMA. The lecture theatres in my college have been invaded by fruit bats. Fruit bats are common in our campus due to lots of trees but they have never made lecture theatres their home. The environmental transmission of rabies and nipah virus is present in my region (India) for sure. Bats and humans should cohabit but not inside lecture theatres. I've spent a lot of time thinking of some effective strategy to drive them out. The officials are planning to poison them but I'm against it. Can you offer some suggestions regarding this?

[luxatioerecta](#)

[Raina] That sounds like an interesting problem. Do the bats interfere with your lectures? I can imagine they would be distracting. I don't know of strategies to drive bats away -- could you close off the lecture theatre when the bats are out feeding at night, so they have to find alternative roosting habitat?

Fair warning, I am neither a mathematician, or biology guru, but I have 2 questions:

1. How does the fact that bats hibernate during winter months impact the speed at which these diseases spread?
2. Within your models, what variables must you account for beyond the obvious (density of population, length of life, speed of disease transmission between bats)?

[jroche15m](#)

1. [Olivier] Only bats in temperate regions hibernate, and these tend to carry fewer diseases. Research from our colleagues in Colorado has shown the hibernation may help rabies virus (which is found in a small number of bats) persist in bat populations through the winter. White Nose Syndrome, which affects only bats, is thought to exhaust bats' energy during hibernation, but I'm not up to date with the latest research on WNS.
2. [Olivier] Before going beyond "the obvious" variables, we need to estimate them properly, which is not easy when dealing with animals that can fly over long distances in inhospitable regions. We try to combine different sources of information on populations (density, migration patterns, reproduction, all of which vary seasonally) and individuals (age, health, presence of antibodies indicating current or past infection...). Disease transmission itself is particularly hard to measure, as we can only detect it after the fact.

How does the virus impact bat population numbers?

Are viruses such as Ebola and Marburg as deadly to bats as to humans?

Do you think it is possible that said viruses have a dormant (lysogenic?) life cycle within immune/surviving bats?

I think this type of research which seeks to prevent catastrophes in the first place are underappreciated that's why I am really grateful to people who work hard in this niche.

[RyanCid](#)

[Olivier] 1. As far as we know, bats seem to tolerate most of the viruses that have been studied recently in relation to spillover. Rabies and related viruses, which kill any infected animal within days, are not always lethal to bats: some of them survive and develop protective immunity. White Nose Syndrome, which is caused by a fungus, is one of very few diseases of bats known to cause a substantial toll on populations. My colleagues have recently reviewed historical records of large mortality events in bats around the world, and very few seem to have been caused by disease:

<http://onlinelibrary.wiley.com/doi/10.1111/mam.12064/full>

1. Persistence of viruses within bats is a hypothesis under investigation, as discussed in our paper (see link at the top of this page), but evidence is still limited, due to practical constraints.

Is it confirmed that bats are a reservoir for filoviruses? I remember reading *The Hot Zone* and Preston mentioned that bats were suspected as a reservoir, but it had never been confirmed.

[IAmKnightSolaire](#)

[Raina] Marburg virus has been isolated from bats on a number of occasions. CDC has done some good viral ecology work on Marburg virus, showing that it persists in populations of *Rousettus aegyptiacus* bats in Uganda. Ebola has not been isolated from bats, however, there are many lines of evidence that suggest that bats are reservoirs (widespread antibodies in bats, successful infection of bats with Ebola in the laboratory without seeing disease, epidemiological connections between bats, seroprevalence and disease, and discovery of Ebola RNA in bats).

Can you explain a little about what immunologically makes bats such effective reservoir hosts of viruses like Hendra and Marburg? Obviously their ability to fly/cover large areas of ground, high population density, dietary habits, exposure to other animals, and other behavioral traits make them good reservoir hosts, but what do we know about how their immune systems can withstand such high infectivity and transmission rates without correspondingly high rates of severe illness and death?

How can we balance the goals of controlling emerging diseases with bat hosts and bat conservation? Obviously bats are extremely important species ecologically (and for their own sake; I think bats are pretty cool!), so the answer to controlling Marburg or Hendra can't just be "eliminate all the bats." Is there work going on that attempts to take both a conservation mindset and an epidemiological mindset into account?

[ladyofthelakeeffect](#)

[Raina] See my answer to one of the earlier questions regarding bat immunology. I'll also add to my answer: some recent work by Michelle Baker's group at CSIRO in Australia found that bats have a high baseline level of innate immunity. She eloquently describes the paradoxes of bat immunity in a popular press article here: <https://theconversation.com/why-bats-dont-get-get-sick-from-the-deadly-diseases-they-carry-55012>. The conservation issues are real and important. Bats are critical for healthy landscapes. We also show that culling and dispersal, in some situations, may make virus spillover worse. Some nice work by Dan Streiker on vampire bat rabies also predicts that culling could make things worse: <http://rspb.royalsocietypublishing.org/content/279/1742/3384>.

When you say "such as" those viruses, are you saying bats are known hosts for Marburg and ebola? I thought the ebola reservoir was unknown... Also, I am a big fan of Laurie Garrett's *The Coming Plague*, have you read it? Do you do any field research in caves and if so, what protective gear do you wear? What led you to epidemiology and then specifically to bats as a disease vector? Thanks.

[Planetsteff](#)

[Olivier] The identification of a disease "reservoir" is a long and uncertain process, it's a real whodunnit! For Ebola, the virus has been found in a small number of animal species, including apes and bats, so they're our usual suspects. If not the virus itself, we can find antibodies in some bats, which show that these animals must have carried the virus at some point and survived. And there is also anecdotal evidence that the latest Ebola outbreak in West Africa started in a village where bats were roosting,

and the "index case" is thought to be a child who may have come in contact with a bat soon before getting sick. For Marburg, Hendra and Nipah viruses, the evidence is much clearer. I recommend reading David Quammen's excellent book "Spillover" to find out about these. We and others are now studying African bat species to understand how they respond to and transmit these viruses, so that we can better estimate the risk to people, but it's not an easy task, as you can imagine. I don't do fieldwork myself, but my colleagues wear appropriate personal protective equipment (gloves, face masks) when handling bats, depending on the species. And they get vaccinated against rabies before starting field work, as a precautionary measure.

So what kind of human pathogen might have a crossover with both bats and say... Pigs?

[Sciencetor2](#)

[Olivier] Nipah virus is the best example. This virus was first identified following a major outbreak that spread across pig farms in Malaysia, and killed pig farmers and family members:

<https://www.cdc.gov/vhf/nipah/>

Thank you for your work! I have 3 questions below :)

1. How difficult is it to get a good number on how many bats in a population are infected by a virus? You mentioned testing urine, feces, etc. in your publication, but how effective is that in pinpointing hosts?
2. Do you think culling would be a efficient option, especially if pinpointing hosts proves difficult? (i.e. there are still hosts unidentified in the population)
3. Could you use similar modeling techniques (as you used in your paper) for white-nose syndrome, even though it is not a zoonotic virus?

[porouspoppies](#)

[Olivier]

1. The difficulty varies greatly among bat species and environments. In Africa, large colonies (sometimes >1 million bats) form every year and then disperse again, and they're very difficult to track. A good monitoring programme was put in place in Australia, collecting urine on large plastic sheets under roosts, allowing virus detection. So we can get reasonable estimates of the prevalence of viruses in particular bat species, but it's hard to tell exactly how many bats carry the virus. But sometimes we cannot detect the virus even though bats have antibodies that indicate they have been infected recently. It could be that the virus is present in small numbers in bats and not always shed.
2. Culling bats has been advocated by policymakers and politicians in several countries, but scientifically it's not a good solution. First, it's very hard to carry out: bats fly away as soon as you try to shoot, catch or smoke them, so you're just moving the problem to a different location. This can easily worsen the problem, especially if stress increases shedding of viruses (which is likely). Second, bats provide very important ecological services, from pest control (insectivorous bats) to pollination and seed dispersal (for fruit bats). So the longer-term cost would outweigh the short-term benefit. We are working on alternative solutions, which can involve vaccines and reduction of bat-human contacts.
3. There is currently a large research effort on WNS, including the use of models. The problem is different because WNS has a lethal effect on bats, unlike the viruses we're studying.

Thank you for your time.

What, if any, effect does the climate the bats live in affect their ability to carry and or transmit infections to humans? Are warmer climate bats better carriers vs their cooler climate brethren?

[Start_button](#)

[Olivier] Climate certainly plays a role, but this can be indirect: for example, bats in temperate climates hibernate in the winter, while some tropical bats migrate to find food according to dry/rain seasons. Viruses will likely be affected by movement and physiological changes in bats. We are also studying the effect of climate along the Eastern coast in Australia, to see if the timing and frequency of Hendra virus spillover events can be linked to climatic factors.

Based on the small amount of knowledge that I have on the subject, researchers have not yet found a direct spillover link between flying foxes and humans when it comes to HeV. Every documented human HeV infection case has been linked to an intermediate host (horse). Whereas, human marburg virus disease and NiV infections have been believed to be linked to excreted bat urine and feces which comes from the reservoir host and not an intermediate host. So I guess I'm just wondering how you're changing your research methods when it comes to studying Hendra, as it seems the mechanism of spillover is much different from the other three viruses you are studying?

[mtip33](#)

[Raina] You are correct. There is no documented spillover of Hendra virus directly from flying foxes to humans--all cases have had a horse intermediate host. Nipah virus, similarly spilled over from bats to pigs and then humans, but is now understood to also be directly transmitted from bats to humans through drinking contaminated date palm sap in Bangladesh. Our paper in PLOS NTD examines the dynamics of these viruses in bat populations. When the prevalence of virus (proportion of bats infected) is high in bat populations, the risk of spillover can also be high --whether this is spillover to horses grazing in paddocks, humans drinking date palm sap, or humans entering a cave with Marburg infected bats. The research methods needed to understand viral prevalence in bat populations are similar in all of these systems. The research needed to understand the human behavioral and immunological aspects of spillover is, however, specific to each system (e.g., horse grazing behavior for Hendra virus, human date palm sap consumption for Nipah virus in Bangladesh, etc.).

Could you describe how you study the bats, and see which bats carry which viruses ?

[GelatinousChaos](#)

[Raina] There are many way to study bats and viruses. One is to lay plastic sheets under bat colonies - -we can collect urine from the sheets and use genetic techniques to identify viruses in the urine. Another way is to catch bats in mist nets and take blood and urine samples from individuals and then analyze the samples with diagnostic techniques to identify viruses or antibodies to viruses.

First of all I agree that understanding these pulses will help prevent future spillover, but how are you determining potential secondary hosts and taking them into account or is the study just focused on previously infected animals? Also, why not include rabies?

[elizone](#)

[Raina] Good question about rabies. Although a number of our coauthors work on rabies, we decided to focus on the emerging pathogens as we know so little about them in bats. We thought that it would be useful to propose strategies for understanding their dynamics in bat populations, given the focus on Ebola etc.

What relevance does the attached image have to your research? Are there a lot of caves in this mountain goat territory?

[illbeoff](#)

[Raina] I don't know why the bighorn sheep is associated with the tweet! I also work on infectious diseases that affect the conservation and recovery of bighorn sheep and perhaps they found the image on my research website! <http://bzndiseaseab.org>

Could you ELI5 what your paper is about?

[linuxgmaer](#)

[Raina] It is about understanding the ecology and epidemiology of viruses in bat populations so we can predict and prevent spillover.

Do bats have T cells? I'm wondering whether bats have the same cellular component as humans, and have never really got a satisfactory answer... I'm interested in how the bats act as a reservoir for viruses without being affected themselves (or maybe they are?)

[MaddingtonFair](#)

[Raina] See our earlier posts about bat immunity. As far as I know bats have T-cells see here <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC4276934/> Also see the links on earlier posts.

Many bat species are endangered. Should we encourage (bat and other) species extinction to reduce the risk of human disease?

[funkiestj](#)

[Raina] bats provide important ecosystem services https://www.bu.edu/cecb/files/2009/08/Kunz-et-al.-Ecosystem-Services_ANYAS-2011.pdf. Fruit and blossom bats pollinate forests and disperse seeds. Insectivorous bats suppress crop pests and an interesting study recently showed that they also suppressed pest-associated fungus of corn <http://www.pnas.org/content/112/40/12438.full> Their ecosystem services may be worth billions and billions worldwide. If we eliminate bats the consequences could be devastating to our natural and agricultural systems. Also, bats are amazing creatures with incredible adaptations such as the ability to fly thousands of kilometers in search of nectar. Loss of these species would be as tragic as losing tigers, pandas, or elephants.

I've always been wondering if the "vampire" actually came from a sickness that is found in bats and transferred to humans, or is this just some kind of old folklore or something.

[I_might_be_high_now](#)

[Raina] That is an interesting question. I found this reference to the etymology of the word 'vampire': https://www.jstor.org/stable/2709546?seq=1#page_scan_tab_contents. According to Wikipedia, vampire bats were only recently associated with vampire folklore (they were discovered in Sth America in the 16th century): https://en.wikipedia.org/wiki/Vampire#Vampire_bats

I am no scientist but I am supremely fascinated by nature and more so by biology and how stuff works. My multi-question is how does a disease manage to change hosts and effect multiple species? Zika, swine flue, ebola, etc. is it evolutionary? is it some innate instinct of spreading to stay alive or are they genetically not tied to any particular species to survive/ spread? Most importantly, how do they even come into existence? did they come from some primordial bacteria billions of years old or are some like cancer and form from our own bodies.

Thanks!

[sirB0nerF4rt](#)

[Olivier] Some microbes are very good at infecting multiple host species, while others become very specialised and infect a single species. These can be seen as alternative strategies favoured by evolution under different conditions. But in addition, a spillover event requires a suitable contact, even indirect, between two host species. We think that part of the reason for the increasing number of emerging diseases in recent decades is because human populations are growing rapidly and encroaching into wildlife habitats.

This question is more addressed to the field research. Do you ever sequence the bat (or other host) genomes to look for rare events of integration/recombination from these viruses? My understanding is that this doesn't really happen at all in these types of viruses, but I wonder how rigorously this has been tested.

[priceQQ](#)

[Olivier] Bat genetics and genomics is an active area of research. I'm not aware of evidence of virus integration, but these are early days. Genome sequences are starting to reveal unusual features of immune systems in bats, which might account for their ability to tolerate virus infection. We're also using bat genetics to assess geographic variations within single species: the less variation there is across large areas, the more migration and mixing must be taking place, which helps spread viruses.

I read a book on this topic by David Quammen called Spillover: Animal Infections and the Next Human Pandemic. I'm guessing you're familiar with it. I've long understood the importance of conserving bat populations, but this book left me feeling a little less enthusiastic about bats. Has your work led you to question whether some bat species might pose such a risk of spillover infection to humans that they should not be conserved?

[BarnabyWoods](#)

[Raina] Bats are getting some bat publicity with all the talk of viruses. However, we think that human activities are contributing to spillover -- for example, in Australia, flying foxes (fruit bats) have lost much of their native forest habitat since European settlement, and are increasingly using urban and peri-urban areas for feeding, thus increasing their contact with horses (the intermediate host of Hendra virus). These bats are important pollinators, as their distribution shifts into peri-urban areas we are losing the important ecosystem services they provide. We need to find solutions that allow bats to continue to migrate and pollinate native forests, and such solutions may also decrease the risk of virus

spillover.

It makes me nervous when I read about studies such as this because I fear that humans will use the data to justify taking extreme measures to control wildlife populations to suit our own needs without regard for the natural world. I get that this is a natural human instinct, but in the end we screw ourselves because fear drives us to do really stupid things. For example: spraying to try to control the mosquito that carries the Zika virus is eradicating the honey bee populations in the U.S. The impact on the human food supply of wiping out one of our most important pollinators is devastating. So who makes these decisions without regard to the impacts they can have on the entire ecosystem? I fear that the knee jerk responses to these situations by people who have no concept of how their decisions will play out in the natural world could ultimately be the end of civilization as we know it.

[BACatCHU](#)

[Olivier] We share your concern: our research actually aims at finding solutions that protect both people and bats. There are very good reasons to protect bats, not only out of regard for the natural world, but also because they play important ecological roles which are crucial to humans. Insectivorous bats are the most efficient and natural insecticide, and fruit bats are important pollinators. We believe that controlling disease can be better achieved by reducing contact between wildlife and people or domestic animals, and, when possible, using vaccines (there is now an efficient Hendra vaccine for horses in Australia).