Conservation in the time of COVID-19: linking biodiversity conservation and human health

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KEVIN OLIVAL [plenary speaker]: Good morning, and thank you for having me. I'm really honored to be presenting at the SCCS-NY conference. It's a great pleasure to give a plenary address to all of you and thank you to Ana and the organizers from the Center for Biodiversity and Conservation at the AMNH for inviting me. Today I'm going to talk to you about something that's really dear to my heart, which is linking biodiversity conservation and our understanding of emerging diseases and in this case zoonotic diseases or those that jump from animals to people, and unfortunately, we are in the midst of a zoonotic disease pandemic caused by SARS coronavirus-2, the virus that causes COVID-19 and what more timely topic I guess than what the organizers have put together in terms of linking conservation and disease and our better understanding of how we can put those two things together. So let me start my screen share here.

Again, a pleasure to be here. I'm just going to give you a quick intro to who I am and where I've come from and how my background sort of has gotten me to this position where I can speak to you about the topic of biodiversity and human health. So I grew up in Hawaii in a fairly small town in coastal Hawaii and that you know that upbringing I think really fostered a love for nature and for respecting the land, the mountains, the ocean, and as I went through school, I clearly was gravitating towards science and biology. I was always a kid who liked to play with bugs in the dirt and things like that. I think as many of you probably did since you've gotten into conservation biology. And you know after I graduated high school I what are you going to do for college? Well, I was I started getting more interested in veterinary medicine because at the time I thought that was a path where you could work with animals and get your hands dirty with animals and it was one of the only paths I was really aware of. And so I went to school at Colorado State University majoring in sort of pre-veterinary medicine which actually evolved into getting more interested in human medicine and anatomy and physiology. And so I started going actually down a pre-med pathway and keeping my options open for veterinary or human medicine. But after college, I actually found out that I really enjoyed getting back to conservation biology and I got one of my first jobs after college back in Hawaii - was working with endangered tree snails, and that got me really interested in conservation genetics, field work, captive breeding and various aspects of conservation.

And then when I went off to grad school, I wanted to continue using genetics to understand conservation problems, but I sort of landed on this project where I was looking at large fruit bats, flying foxes in Southeast Asia, and not only understanding the genetics and the conservation of those bats, but also that they are host to an important emerging disease called Nipah virus. And so how could I link understanding of Nipah virus ecology with the bat genetics and the bat conservation. And that was you know more than I don't even know - 15 years ago, 18 years ago - and that really set me on

this path to sort of bringing those two aspects together. So without further ado, let's get into the talk and especially thinking about the time of COVID.

So yes, we've hit unfortunately the grim milestone of more than 1 million people on the planet have died from COVID-19. That number is no doubt much larger than 1 million, but due to imperfect surveillance, of course, we only are able to diagnose and definitively state that a million people have, over a million people have died from this pandemic. Tragic, absolutely tragic and devastating, in that we're not at the end of this yet and unfortunately cases continue to grow around the world.

So how did this little tiny speck of protein and nucleic acid - there's a picture of SARS coronavirus, about a hundred nanometers across - how did this little virus bring, devastate economies, restructure societies, and change our daily behavior and our society, and where did it come from? Well, some of you might not be old enough really to remember the details of SARS-1, but SARS coronavirus back in 2003 was a new coronavirus that was first detected that came out of southern China and rapidly spread around the world. Luckily, due to Public Health measures and some characteristics of the virus, notably that it wasn't transmitted very well before people were infectious, which is different than what we're facing now with SARS-COVID-2, that it was controlled and contained in about 800 something people died worldwide and know about over 8,000 were infected had about a 10% mortality rate, but was able to be controlled.

Another new coronavirus - the Middle East Respiratory Syndrome coronavirus emerged, was first detected in Saudi Arabia in 2012. Now that virus has been linked to camels, and people have been infected multiple times through direct exposure to camel populations.

Now these are just two examples, and there are actually hundreds of new emerging infectious diseases we call EIDs that have sprung up over the last 70 years or so around the world in what we call these disease emerging hot spots around the world. And this is a screenshot from an online data repository that we've been putting together, EcoHealth Alliance, starting back in 2004 and really just trying to collate the first instance where we've actually first detected a new disease emerging in the human population. And there's quite a few of these events, and what you'll see, and this is a figure from Jones et al. paper in 2008 that the number of these events, these new disease emergence events, has been growing over time over the last several decades. You see a greater number of new emerging diseases every year and if you look at this bar chart, the white section of the bars are actually zoonotic diseases that have come from wildlife. Right, and the sort of red area are non-wildlife or livestock emergence and the orange are sort of unspecified but of animal origin. So, you see that the majority of these new disease events actually come from animals, and a large number of them come from wildlife - not directly through livestock, but actually from wildlife exposure and wildlife populations.

So, what about SARS coronavirus-2, COVID-19? Where did that come from? Well, you know you have to sort of play disease detective a bit when you try to unravel these

mysteries, and when a new disease emerges in the human population, for one of the first steps is obviously controlling the outbreak in people. The next step is identifying what is the causative agent? And so that can often take a lot of work in terms of virology work and screening and genomic characterization, but because of the rapid advance of science we were actually able, we the global community, able to rapidly sequence SARS coronavirus-2 and publish that sequence and share that around the world within weeks of its first detection, which is quite remarkable. It took actually months for the same information to be shared for example for SARS in 2003.

So, we have the advantage of this scientific and public health infrastructure now, but that still doesn't tell us exactly where it came from. What we do know, in part from a large body of work that we've been part of in China looking at coronaviruses and wildlife, is that the new virus SARS CoV-2 is very closely related to a whole group - and this is a whole cluster you can see this clade of that related SARS related coronavirus is from bats, and this is a network diagram of genetics of those viruses, but you can see there SARS-CoV-2 and there's a little virus that's highlighted there in the blue color, which is a virus that was found years ago from *Rhinolophus affinis*, a horseshoe nose bat that has a 96 percent genetic similarity to SARS coronavirus. So, it looks like it's a bat origin virus and all the evidence points to that, but we don't know exactly how this virus got from a bat to a person. There may have been other hosts involved. There may have been livestock or other animals and the wildlife trade involved where the virus jump between species, was transmitted between species before it got into a person, or it could have gotten directly from a bat to a person, we don't know.

Was this surprising? Well, not completely. Years ago and back from 2005 to 2013 our scientists at Ecohealth Alliance in collaboration with a big team around the world and from China have published on a number of these new SARS related viruses that have been found in nature, and it turns out some of them are able to infect human cells - and that's what that figure is showing you from this paper - but some of them are not and you know, you might have a big diversity of viruses existing in nature, not all of them are equally scary or pose a threat to human health, but it takes kind of a lot of scientific work to figure out which ones do and which ones don't, and that's very important process that we need to be thinking about.

And indeed, we've actually showed exposure to SARS related coronaviruses in populations before human populations before COVID-19 emerged. This is a paper published in 2018 where we showed there's serological evidence, antibodies in these rural populations of people that live near bat caves and rural China and were potentially exposed to these related viruses and there was not a large outbreak and a big spread, but it looks like there was spillover where that initial transmission from an animal to a person could have been happening in years prior to the outbreak we're witnessing now.

So that's a bit of a wake-up call, right? And what it tells you is not that we need to be afraid of bats and I'm going to get more into this later, but that there are some human behaviors and exposures and how we interact with wildlife that are important that we need to understand and similarly it's very important that we create these early warning

systems so that when a new disease does emerge we have the ability to identify it and hopefully snuff it out before it spreads any further.

So, let's think, let's step back and think about the ecological process. How did these new diseases come about? And I do a lot of research on bats so I'm going to use bats as an example here, but you could substitute any of your favorite mammal or other wildlife, you know, we know that emerging infectious diseases that get into the human population come from all different mammals primarily, but also birds and other animals, especially for influenza viruses waterbirds for example are a big source of those. So, all mammals carry a big diversity of viruses. We can think of this viral diversity is sort of a natural part of biodiversity. It's a natural part of our ecosystem. These viruses have co-evolved with their hosts for millennia if not many hundreds of thousands of years and in the process, they've diversified. You know, bats don't exist, most bats are not solitary although some are, but bats live in groups, roost in colonies of multiple individuals. It's also important to understand the population dynamics of those bats. And how is the virus just a natural part of those dynamics and how does the virus sort of spread from adult to juvenile, parts of the population, or from individual from individual. So, you know ecological techniques like radio tracking and population genetics can really come into play here to understand those dynamics.

And of course there are multiple species that occur in a given area and we really need to understand how do those different species interact, again, and thinking specifically about viral emergence in viral diversity, you know, how are the how does the evolution of these pathogens and host go hand-in-hand with their community ecology and how our say viruses spread from one species to another also relates to your understanding, our understanding of community interactions.

And then there's a big question of well, how many viruses are there in nature that exist out there that are, you know, potentially some of them pose or poised rather to jump into the human population, and you know, we estimate that there's over a million of them. Some estimates are lower than that depending on how you calculate it. But these are ecological questions that biodiversity scientists have been grappling with for decades, right? How many species are on the planet?

Well, we can take some of those same tools and looking at species saturation curves and understanding community dynamics to get a handle on the viral diversity or the virodiversity of the world. And these are these are important questions for human health, but they're also important questions as biodiversity scientists.

And these species do not exist in a vacuum, right? So, thinking about community ecology, well, how are those animals and their viruses interacting with the plants, the abiotic environment and all the other things that we think of as a full ecological system and so we could call this field of study as viral ecology.

And let's not forget that we humans are part of that ecology. Of course, you all know that but it's a good reminder as we as we think about emerging diseases is that we are

interacting with this these ecosystems in new and unprecedented ways, including things like hunting animals. Here's a picture I took of a bat hunter from Vietnam. Bare hands, he was later going to prepare that animal for food, sell it off to the markets.

So, we're coming into direct contact with animals through our own actions. And we're also coming into sort of indirect contact with animals and rapidly changing the planet and things like deforestation, you know, are strongly linked to disease emergence and I'll get into that a little bit more in a second.

But as we cut down forests, well, we need to - we're going deeper into natural habitats, and we're disrupting the ecological system of species that have lived in those habitats again for thousands of years, but now we're a new host where a new susceptible naive host potentially for some of these viruses and we are intruding into that world that was previously a balanced ecosystem.

So this is really, I think, the crux of the talk is that the underlying risk factors for disease emergence or viral emergence, and we can rank these, and land use change and deforestation are towards the top of that list, in terms of driving past disease emergence events. And the wildlife trade, which was strongly linked to the emergence of SARS coronavirus-1 and many suspect also linked to the emergence of COVID-19. By trading live animals people have direct exposure to their viruses and we're also putting animals together in situations where they would not exist together in nature in these live animal markets. And then agricultural livestock expansion, again, we're creating sort of these opportunities for viruses to jump into different species. Sometimes it goes through a livestock reservoir before it comes into the human population. And Nipah virus that I mentioned before is a really good example of this where it spread from bats, where it most certainly evolved for thousands of years, into pig populations as these pig farms were being expanded in Malaysia and sort of these tropical regions near good bat habitat, you had an opportunity for the virus to jump from a bat to a pig and then in that naive pig population the virus spread rampantly and most of the people who are affected in the initial outbreak were pig farmers and slaughterhouse workers.

So, these are the really the primary risk factors that drive disease emergence. These are anthropogenic events, right, human-induced events that drive new diseases to emerge. And that's a really important thing to remember and I think it's also a powerful positive thing to think about is that if we're the cause of these outbreaks, we also have the power to reverse the trend and to then hopefully decrease the number of new emerging diseases in the future.

But of course, as you all know as a group of conservation biologists, these are also the primary threats to biodiversity around the world: deforestation, wildlife trade, human expansion into native habitat. These are the factors that cause species to go extinct and they also are the same factors that cause diseases to emerge.

So, we've ranked these risk factors globally. So, we've taken those 400 new emerging disease events that I showed you before and mapped each of those out on the planet

and looked at spatial correlates by overlaying those layers. We use some machine learning methods to then rank the risk factors for the variables that are most important that explain that location of disease emergence. And what you see might be a little difficult to see this graph but there are a number of both environmental factors like areas where there's rich biodiversity is an underlying important factor, mammalian biodiversity, and there's also a factor or spatial factors that explain human activity, like how much land is under pasture, obviously human population density is an important correlate. Cropland and cropland change, the sort of the pace of change of the environment in that area. So together we can put all these factors together and actually look at where are the hot spots for new emerging zoonotic diseases? And this is part of that same publication a few years ago where we mapped out and the areas in yellow are a higher risk for the next new emerging disease and you see, well Central China where COVID-19 emerged is a very hot spot, as well as other areas of the planet where we know there's rich biodiversity, but there's also a large human population and a high human population density. It's really the confluence of human population, mammal biodiversity, and ecological change where new diseases emerge and where you have these hotspots for disease emergence.

Again, this gives me actually a little bit of hope because the whole planet is not a risk factor for new diseases emerging from wildlife. There are actually specific regions of the planet where we can focus our energy.

So let's get back to the title to talk and think about, you know, SARS coronavirus-2, COVID-19 specifically, and how, you know, what's it like to be a conservation biologist in this time, and how is SARS-CoV-2 to a threat to conservation?

Well, we're a resilient bunch, the conservation biologists, and this is a figure I found from a paper published in 2009 from Hanson et al. that I thought was quite interesting and that look mapped out the 34 biodiversity hotspots around the world. According to Mittermeier from 2004 and on top of that showed you the location of all the armed conflicts around the world, basically the wars around the world where there have been more than a thousand human casualties from 1950 to 2000.

So there's a lot of unrest in some of these biodiversity hotspots, yet conservation biologists have been working in these regions and sometimes against many perils to their own safety, working hard to conserve biodiversity. So, you know, we've dealt with continuing conservation in difficult times and COVID-19 is sort of a new a new threat, a new level of threat in terms of getting the work done on the ground, but I don't think it's going to stop people, in a lot of research and a lot of wildlife protection is still going on around the world.

So, you know one thing that's important to think about is not just do we get viruses from wildlife, but can we give those viruses back, our viruses, back to wildlife and thinking about SARS coronavirus-2, well, we know that some species are susceptible to the virus and getting the virus from people specifically. We saw outbreaks of SARS-CoV-2 in live mink farms and fur farms in Europe where a large number of animals were dying

from the coronavirus after they got it from some of the workers in those farms. So there's different susceptibility among different species, you know, certain felids seem quite susceptible as well as other carnivores, but there's a lot that we don't know about susceptibility. So how do we take a precautionary approach when we're working with wildlife to avoid infecting them? Well, these are some pictures of people handling bats with no gloves. An old technique where you blow on the bats fur to expose their reproductive organs to sex them or to see if they're lactating or to stop them from biting you, right? And these are not recommended actions. In fact, I'll get to it in a second but there are simple ways to prevent this risk of spill back or the risk of the virus could get from a person back to an animal and of course many people are infected with COVID-19 are not symptomatic. So, this is a real thing to be thinking about.

Just a couple weeks ago we published the paper looking at, you know, the risk that SARS-CoV-2 could have to North American bats, you know, are North American bats naive to these SARS-related coronaviruses. Yes, we know that bats do carry SARS-related coronavirues in Asia, but those are a different group of bats. And what we have in North America is no evidence, you can see in Figure A here, the SARS-related or Sarbeco coronaviruses, there's no evidence that are any of these viruses naturally occurring in the Americas, and so an introduction into the American bat populations would be a new emerging disease event and we don't know what the susceptibility of this species could be, but it could be a profound change if that virus then became established.

And of course, you know, diseases have spread from people to bats in North America before, so white nose syndrome is a fungal pathogen and it was most likely brought to the U.S., to New York State specifically, from probably spores on somebody's clothing who maybe wandered into a cave, a tourist cave and those spores got into the environment and then set off an epizootic of unprecedented scale that has killed millions and millions of bats across North America. So, disease itself is a conservation issue and I think white nose is a prime example of that, that just the introduction of disease can cause dramatic and wide scale conservation disruption in terms of decline in populations. Some of the North American bat populations are more than ninety percent below their peak in different areas.

And so some of this guidance has been codified, our team at EcoHealth Alliance was involved with putting together this document from the IUCN wildlife Health Specialist Group and OIE jointly, and it's translated into English Spanish and French, so I leave that to you to look up and download, but here's a figure from that, those guidelines. So, you know, simple precautions that field biologists can take to reduce the exposure that they might have by accidentally passing COVID-19 onto other species. And these are things we need to really keep in mind as conservation biologists. And similarly, at EcoHealth Alliance we've been involved with training our field staff for decades now in terms of wearing personal protective equipment while doing this work. Much of the impetus of that was to protect ourselves from any exposure to viruses, but of course it goes both ways. And if you're wearing the proper mask you are also protecting the

animals from exposure to any of your viruses. So here is just a photo from our team in Pakistan on a project that I'm helping to lead looking at bats.

And again, a bat specific example, but there are also you know new technologies where we can move away from sort of less invasive approaches to wildlife management and wildlife surveys. So here is a handheld echolocation detector. And this is a way to passively monitor a bat population without the need to do mark-recapture and to catch animals. So, can we shift some of our, you know our methods to be a little more non-invasive and socially distance if you will as we're working with wildlife.

And an important, you know, another important negative consequence of COVID-19 on wildlife conservation is misinformation and negative backlash. So, a few years ago, we published a paper that showed that bats do carry a large number of zoonotic viruses relative to other groups of mammals. And of course the headlines that came out of that paper, some of them were a bit, you know, attention-grabbing in terms of do bats carry more dangerous pathogens and other groups and predicting the next pandemic and even as far as bats are the number one carriers of disease - now, of course, we talked with journalists, but we don't have editorial control over how those headlines are always drafted. And so how do we get ahead of the curve? And we've been thinking about this for years, but it's more important now than ever in terms of COVID-19 so that there is not a backlash. There's not communities that go out to try and cull animals because they're afraid.

And we've seen, we've heard about a little bit of anecdotal evidence of this is happening unfortunately in some areas.

This is a nice paper by Ricardo Rocha et al. that I was part of with a large group and thinking about again for bat conservation, how do we get ahead of that negative backlash in terms of COVID-19? And planning for and mitigating some of that backlash in advance as best we can.

And perhaps the most systemic threat that COVID-19 poses to conservation is in terms of funding and support. This was a nice paper from Lindsey et al. in Nature Ecology and Evolution looking at specifically thinking about conservation in Africa, how might COVID-19 impact conservation dollars? And I'll just scroll through this the schematic which I thought was quite nice, you know, the COVID pandemic is impacting both African economies and international economies and dramatically decrease in the amount of eco-tourism that those countries are seeing.

All of that together is reducing philanthropic dollars, state-funded conservation dollars, which is going to then impact the effectiveness and the ability for protected area managers and other conservationists who manage declines.

And, you know, that could lead to biodiversity losses, and with a decrease in sort of oversight, it could also lead to increased poaching and other negative consequences. So how do we develop sort of new resilient models for conservation amidst these

challenges and amidst potentially a lack of funding and I think that's a key question as we move forward as conservationists, and here's a few thoughts on that.

So I think COVID-19 also represents an opportunity and this is something that my organization EcoHealth Alliance and our scientists have been talking about for years now, but really this is the moment to seize on this opportunity and the positive thing that I'm saying is that there really is a much greater recognition that biodiversity threats like wildlife trade and ecosystem change or deforestation are major drivers for disease emergence.

Not too many people are arguing with that now. People are listening that the science is telling us that these aspects are linked together and if we don't conserve biodiversity and, you know, limit things like the wildlife trade, you know, there's been calls for banning the wildlife trade in China after COVID-19 emerged with some success as well as around the world. Then if we don't address those underlying factors, we're not going to address future disease emergence.

This is a paper from Science, I encourage you to all read, looking at the economics of pandemic prevention and our president at EcoHealth Alliance, Peter Daszak, contributed to this manuscript and here's a quote from from the paper, which I think is really sums up the main findings is that they look at a bunch of different categories of pandemic prevention, ecological strategies for pandemic prevention, like just paying to protect areas, reducing carbon emissions, reducing the wildlife trade, paying into, you know, approaches to reduce the wildlife trade. And those all cost billions and billions of dollars around the world. But if you add it up prevention costs over 10 years will only be about two percent the cost of the COVID pandemic as it was estimated at the time. It could be even less. So, this is a drop in the bucket. Prevention, you know as the saying goes, is a drop of what is the what is the expression an ounce of prevention something like that? But a tiny bit of prevention can have huge impacts in terms of safeguarding both biodiversity and our own health.

And this is being really adopted at the highest level. So here is, there will be soon forthcoming a big report released by The Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services, IPBES, and some of our colleagues at EcoHealth have contributed to that report. It's going to be, I think, quite an important one when it comes out in terms of linking biodiversity and pandemic prevention. And of course, this scales down to a community level. So we've been working with communities with a sort of a community engagement booklet, that we call 'Living Safely with Bats' that got people that made communities aware of the positive value that bats serve in the environment in terms of pollination, seed dispersal, insect control, vector insect control even. And how you know, we can live safely with these animals and also prevent the risk of spillover through very simple mitigation measures like, you know, protecting yourself of the mask when you go into a bat cave if you're harvesting guano and other activities that community members might be participating in.

And I also have hope and this is a project that I'm helping to lead, the Western Asia Bat Research Network that there are new initiatives being developed that are integrating conservation biologists and disease experts and public health experts from the start so that we're building these networks are not trying to retrofit them after the fact in terms of making them public health aware. But in some cases you have very long-standing established conservation networks, like this is a southeast Asia Bat Conservation Research Unit that I've been part of for a number of years and I've helped sort of do some integrated training with these conservation biologists in terms of thinking about personal protective equipment and protecting both bat health and human health while we do research.

And lastly what gives me hope is all of you in the audience and really thinking about the diverse disciplines that you bring to the table and that you will continue to bring it to the table as we develop this field of what we call One Health research, right? Integrating human health with wildlife health and ecosystem health and domestic animal or veterinary health together. And it really does take a village, it takes a lot of different disciplines.

Here's just a list of some of the disciplines that are relevant to understanding zoonotic disease emergence, and conservation biologists I strongly believe are key to that effort and you will all be key to that effort going forward. So I encourage you to, you know, reach out to colleagues who are working in fields outside of your own. When you go to a conference, go to talks that you would not normally go to and, you know, and start collaborations. They don't always have to be funded collaborations, but you know write a paper with your colleagues from different disciplines and start thinking outside of the box.

And I think with that approach we have a much brighter future in terms of addressing COVID-19 and continuing our important work but also in terms of preventing the next new emerging disease, which is no doubt going to happen in the future.

So thank you for that. I really appreciate your time and I'm looking forward to the questions and answering. Here's some of our funders.

And I look forward to interacting with all of you throughout the rest of this virtual conference. Thank you.