Cornell University
College of Veterinary Medicine

Wildlife Health Cornell

A College of Veterinary Medicine Center of Excellence

Because we need nature, and nature needs us
Fall 2017

Wildlife Health Cornell Takes New Approach to Natural World

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Wildlife Health Cornell has grown out of a sense of genuine urgency regarding the fate of our planet's wildlife, an increasing understanding of our own dependence on the world's natural systems, and the recognition that it will take a new generation of colleagues to halt and reverse the trends we face. Our vision is to ensure a healthy future for wildlife, people, and planet by emphasizing the types of interdisciplinary collaboration often required to foster real progress along the science to policy and action continuum. Representing an unprecedented approach to the health challenges wild animals face around the world, Wildlife Health Cornell works with governments, local communities, and the private sector to improve scientific knowledge, enhance environmental stewardship, and build capacity for sustainable change.

During Cornell University's Reunion 2017, Wildlife Health Cornell held a "talk show" launch event, hosted by Provost Michael I. Kotlikoff and featuring our novel approach to wildlife conservation and the challenges of saving wildlife and wild places. Watch a video of the full launch event.

For more information on the work of the Wildlife Health Cornell Center of Excellence, please visit https://www2.vet.cornell.edu/wildlifehealthcornell. We hope you find this e-newsletter useful and thought-provoking.

- Steve Osofsky, DVM
Jay Hyman Professor of Wildlife Health & Health Policy

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Cattle, Conservation & Collaboration

Cornell researchers and partners are developing novel approaches for mitigating conflicts between livestock agriculture and wildlife conservation in southern Africa, where both sectors are vital to people and planet.

Bald Eagles Face New Threats

The comeback of the American bald eagle is a success story across the nation, but now these magnificent birds are facing another threat. Watch this video to see what Cornell scientists are doing to help determine the sources and impacts of lead in New York bald eagles.

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Healthy Oceans

We depend on the oceans in many direct and indirect ways. Cornell is helping scientists learn how to better help the public understand, and address, the problems facing the world's seas.

Critically Endangered Javan Rhinos

In Indonesia, Wildlife Health Cornell scientists and partners are monitoring potential disease threats to the critically endangered Javan rhino as plans move forward to expand their habitat.

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Saving One Wild Life at a Time

The Wildlife Health Cornell team at the Swanson Wildlife Health Center and local rehabilitators saved the life of a wild bobcat hit by a car in Lansing, New York.

Students Discover Passports to Planetary Health

This past summer, Cornell's Expanding Horizons program helped 14 College of Veterinary Medicine students address challenges impacting wildlife, domestic animal, and human health across the developing world.

Inaugural Planetary Health Meeting

College of Veterinary Medicine faculty led multiple sessions at the inaugural Planetary Health Alliance Annual Meeting, which brought together a diverse group of researchers, students, and policy makers committed to understanding and addressing the human health impacts of global environmental change.

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Wildlife Health Cornell, a College of Veterinary Medicine Center of Excellence, represents an unprecedented approach to the health challenges wild animals face here in the northeast U.S. and around the world - a comprehensive, science-based response by a team of the world's top wildlife health experts. With an emphasis on the types of interdisciplinary collaboration often required to foster real progress along the science to policy and action continuum, Wildlife Health Cornell has grown out of a palpable sense of genuine urgency regarding the fate of our planet's wildlife, an increasing understanding of our own dependence on the planet's natural systems, and the recognition that it will take a new generation of colleagues to halt and reverse the trends we face.

To learn more about Wildlife Health Cornell, please contact Dr. Steve Osofsky at s.osofsky@cornell.edu or visit our website.

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Cattle, Conservation, and Collaboration

Can livestock agriculture and wildlife conservation coexist in areas of the world where they are in conflict but vital to people and planet?

Featured

Steven A. Osofsky
Population Medicine and Diagnostic Sciences, College of Veterinary Medicine

by Jackie Swift

In the early 1990s, Steven A. Osofsky, Population Medicine and Diagnostic Sciences, was a young wildlife veterinarian recently graduated from Cornell and headed for southern Africa. One of the first things he noticed when he got there were the thousands of miles of fences covering the land. They were there to keep domestic beef cattle separated from wild buffalo because buffalo carry the virus for foot and mouth disease (FMD), which can sicken cattle and cause trade embargoes on beef from affected countries.

The fences also cut across the ancient migratory routes of the region's historically vast ungulate herds, with devastating consequences.

"Hundreds of thousands, if not millions, of animals have died along these fences since the 1950s because they couldn't get access to seasonal grazing and fresh water," Osofsky says. There was intense conflict between the livestock and wildlife sectors, and as Botswana's first official wildlife veterinarian, Osofsky saw it firsthand.

"Botswana is one of the last great places on earth for free-ranging wildlife," he says. "But fences are a barrier to the habitat connectivity these species evolved with over millennia, and they've significantly impacted the region's wildlife. I've spent a lot of time since the 1990s thinking about this land-use conundrum, wherein two sectors have been seen as impacting each other in such dramatically negative ways."

The One Health Strategy

Osofsky's concerns for wildlife and human wellbeing drove him to help catalyze an approach called One Health. "This is the overriding theme of most of my work," he says. "My focus is very much on wildlife conservation and the ways in which we can be better stewards of the environment and how that relates back to the health of wildlife, domestic animals, and people."

> "Botswana is one of the last great places on earth for free-ranging wildlife… fences are a barrier to the habitat connectivity these species evolved with over millennia, and they've significantly impacted the region's wildlife."

The One Health approach led to Osofsky facilitating dialogue with southern African governments, international donors, the World Organization for Animal Health (OIE), the Food and Agriculture Organization of the United Nations, small farmers and farming communities, and others with a stake in the clash between the needs of wildlife and those of beef farmers in the region. He and his team worked with colleagues in the Southern African Development Community to identify the crux of the problem.

The international rules regarding the management of animal diseases were based on geography. The OIE's regulatory framework had long required any aspiring beef-exporting country or region where FMD was present in wildlife to physically separate wildlife from livestock. This led governments in southern Africa to erect extensive fences.

With today's scientific understanding and sophisticated food safety protocols, Osofsky and his colleagues concluded that the OIE's goals could be equally well served by focusing on the beef production process. Osofsky says, "Whether you're talking about *E. coli* or FMD or a parasite, how you deal with the product from a biosafety viewpoint is what you really need to worry about."

Osofsky continues, "You can process meat, vegetables, or any food by using standardized approaches based on good science, farm to fork as they say, to make sure the end products are safe for human consumption, while at the same time ensuring that a product like beef doesn't spread an animal disease. It took many years of dialogue before the OIE acknowledged that what is essentially a food safety approach is equivalent to the geographic, fence-based approach." In 2015 the OIE's World Animal Health Assembly updated OIE guidelines so that fences were no longer the only option for managing FMD in southern Africa.

Planetary Health, Innovation via Integration

As Osofsky worked on the fence problem in southern Africa as well as other environmental and wildlife conservation issues, he was able to utilize health concerns to gain policy traction. Eventually he brought together a diverse array of colleagues to help develop a new field subsequently dubbed Planetary Health by The Rockefeller Foundation.

"Planetary Health is about improving both our understanding of the public health impacts of anthropogenic environmental change and our ability to measure them," he says. "This can then improve decision making in the realms of land-use planning, ocean-use planning, environmental conservation, and public health policy. If governments want to dam the Amazon River's tributaries for hydroelectric energy, for example, but project assessments neglect to look at the millions of people who depend on migratory fish in that freshwater basin for protein and micronutrient nutrition, then we could be missing one of the largest real costs resulting from the dams. Many infrastructure projects have both positive and negative public health impacts. If we do a more thorough job assessing these impacts, we should make better-informed, more sustainable decisions."

Wildlife Health Cornell, a Center of Excellence

In 2016 Osofsky came full circle and joined the faculty of Cornell's College of Veterinary Medicine. He brought with him a vision of the college as a leader in wildlife health. One of his first steps was to help develop a flagship program called Wildlife Health Cornell, a College of Veterinary Medicine Center of Excellence.

"The array of exciting wildlife health work underway across the veterinary college, much of it involving other parts of the university as well as external partners, creates a window of opportunity to build a real community of practice," Osofsky says. "Wildlife Health Cornell is a way to capture all of the neat things the college is doing—and can do, going forward—to make sure we share what we're learning across campus and around the world."

In March 2017, the College of Veterinary Medicine received $1.7 million over three years from The Rockefeller Foundation to support Osofsky's work. With part of the funding, the Osofsky team is evaluating real-world applications of Planetary Health science policy. Their work will help inform policymakers at a range of scales so that the public health and wellbeing impacts of alterations to natural systems that people depend on are more proactively taken into account.

The other portion of the grant—as well as additional funding from the Atkinson Center for a Sustainable Future's Academic Venture Fund—will help local beef farmers living with wildlife in southern Africa undertake the next steps toward being able to sell their beef on the world market and will support the reevaluation of some of the fences impacting migratory wildlife.

KAZA, a Global Treasure

The focus is on the Kavango Zambezi (KAZA) Transfrontier Conservation Area, a conservation and development initiative that spans five countries—Botswana, Namibia, Angola, Zambia, and Zimbabwe. KAZA's wilderness is a global treasure and is home to roughly half of all remaining African elephants and many other endangered and threatened species.

Osofsky says countries like Botswana want to move the new approach to beef production forward. They have welcomed Cornell's technical support. In the fall of 2017, Osofsky is taking a team with him to Botswana, including Randy W. Worobo, Food Science; wildlife ecologist Shirley Atkinson from Osofsky's own team at the veterinary college; and leading southern African FMD experts and wildlife biologists.

Osofsky is optimistic that if this new approach to beef trade takes hold and the most problematic fences can be realigned or taken down, the historic migrations will return. A successful outcome for both the livestock and wildlife sectors could be a real boost for transfrontier conservation and the sustainable development it is meant to engender. "There was an old fenceline in Botswana that got opened up a few years ago," he says. "There were no living zebras that had ever made their ancestral migration across the region. And yet, as soon as the fence was no longer a barrier, the migration was restored. The zebras followed the same route used by previous generations. That tells me it's not too late."

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Bald eagles face deadly threat from lead poisoning

By ANGELICA A. MORRISON (/PEOPLE/ANGELICA-MORRISON) & JIM LEVULIS • MAY 31, 2017

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Necropsy at N.Y. Department of Environmental Conservation

JIM LEVULIS, WAMC

The comeback of the American bald eagle is a success story across the Great Lakes region, and keeping them safe is a high priority for many environmental professionals. But one serious threat to the great raptor is lead poisoning.

Listen

3:29

Angelica A. Morrison reports

In New York, environmental officials are closely monitoring the problem. Biologists and researchers have noticed a disturbing trend: an increase in lead-related deaths.

“It’s definitely something we should keep an eye on,” said Kevin Hynes, a biologist with the state Department of Environmental Conservation.

Dead birds from the wild or from wildlife rehabilitators are taken to the agency's office near Albany. There Hynes performs a necropsy, which is like an autopsy.

Right now, the number of lead-related deaths in New York is small, but the trend is concerning. There were two deaths in 2009 and nine last year.

(http://mediad.publicbroadcasting.net/p/wbfo2/files/st

Examination on a bald eagle.

CREDIT PHOTO BY JAMES LEVULIS

And those are only the reported deaths from birds found by hikers or brought in from animal rehabilitators. The total may be higher.

“No amount of lead is normal in a biological system,” said Julia Ponder, executive director of The Raptor Center. The non-profit, which operates out of the University of Minnesota, has been keeping track of the deaths.

Ponder said close to 90 percent of the eagles the center takes in have lead exposure, and 25 to 30 percent have lead poisoning. Most of the birds with lead poisoning die.

The U.S. Fish and Wildlife Service's most recent estimates showed 143,000 bald eagles nationwide. That includes more than 3,000 in the Great Lakes region.

Minnesota has more than 1,300 eagles, the most in the region. In New York, the DEC estimates there were 370 nesting pairs last year, up from 110 in the early 2000s.

(http://mediad.publicbroadcasting.net/p/wbfo2/files/styles/x_large/public/201704/april_landschoot2.jpg)

Bald Eagle tends to a newly born eaglette, Spring 2017

CREDIT PHOTO BY APRIL LANDSCHOOT / BALD EAGLE TENDS TO A NEWLY BORN EAGLETTE, SPRING 2017

The increase in deaths could be occurring because the eagle population has been on the rise in some states.

“We have more eagles now than we ever did,” Hynes said. “It could also be related to different hunting practices. We’ve opened up more areas in New York to rifle hunting ... . So there might be more available rifle-killed deer gut piles or carcass parts on the landscape.”

Gut piles offer an easy meal -- but can be toxic. Eagles feast on the field dressings of animals shot with lead ammunition, which is used by hunters because of its affordability and availability.

An eagle with lead poisoning usually displays symptoms like paralysis, lack of appetite and blindness. They may show signs of brain damage and developmental issues -- one reason why they sometimes fly into trains or vehicles.

“When we talk about lead in humans, it's children and pregnant women who are most affected, because of brain development. So it’s really challenging in wildlife to actually assess that, ‘Maybe this eagle has a neurological deficit because it consumed lead at some point,’” said Krysten L. Schuler, a wildlife disease ecologist with the Animal Health Diagnostic Center at Cornell University College of Veterinary Medicine.

- Video: Bald Eagle Necropsy, by James Levulis / WAMC Radio (http://greatlakestoday.org/post/video-bald-eagle-necropsy-nys-dec)
- Photo Gallery: Bald Eagle Necropsy by James Levulis / WAMC Radio (http://greatlakestoday.org/post/photo-gallery-bald-eagle-necropsy)
- Photo Gallery: Bald Eagle family nests near Lake Ontario, by April Landschoot / Listener submission (http://greatlakestoday.org/post/photo-gallery-bald-eagle-family-near-lake-ontario)

Schuler has been collaborating with Hynes and the DEC to generate more data on lead-related eagle deaths. She’s in the early stages of gathering data for New York, Pennsylvania and Maine, and hopes to compile information for the Great Lakes region as well.

So far, Schuler has found that the majority of lead-related eagle deaths involved breeding-age birds.

And though the population is growing in New York State, she wonders, “... is it being sort of artificially suppressed, because we still have this toxin that they’re dying from?”

The key to solving the problem, Schuler says, is teaching hunters not to use lead ammunition for game. The use of lead ammunition for waterfowl hunting is already banned nationwide.

"It's just letting [hunters] know that birds are still dying from lead poisoning," she said. "And, they don't necessarily have to be."

Online Resources

- Ammunition: Non-lead or Lead? (http://www.dec.ny.gov/outdoor/48420.html)
- www.huntingwithnonlead.org/ (http://www.huntingwithnonlead.org/)

(http://mediad.publicbroadcasting.net/p/wbfo2/files/styles/x_large/public/201704/april_landschoot1.jpg)

Bald Eagle pair tends to a newly born eaglette, Spring 2017

CREDIT PHOTO BY APRIL LANDSCHOOT / BALD EAGLE PAIR TENDS TO A NEWLY BORN EAGLETTE, SPRING 2017

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Suzie Gilbert • 6 months ago

How can you not mention the Trump administration's overturning the recent ban on lead ammunition, which is the main cause of lead poisoning in raptors? Steel shot is pennies more expensive than lead. Environmentalists never wanted to take away hunters' guns, just their lead. Our national symbol was no match for cynicism, callousness and greed.

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To increase ocean literacy, narratives hold promise

Students from Georgia, USA, learn about the ocean. Researcher Amelia Greiner Safi says that building ocean literacy may mean giving people relateable "entry points" like beaches. Photo: UGA College of Ag & Environmental Science

(http://futureearth.org/sites/default/files/styles/full_blog_image/public/field/image/ocean_education.jpg?itok=QUWi-zLT)

JUN 2017 7

by Daniel Strain (/blog/people/daniel-strain), Amelia Greiner Safi (/blog/people/amelia-greiner-safi)

In a new Q&A, Amelia Greiner Safi of Cornell University talks about how the scientific community can help the public to care about, and act on, the problems facing the world's seas.

You can find more information about Future Earth events at the UN Ocean Conference here (/news/ocean-conference).

Most people on Earth, even those living in land-locked countries, depend on the ocean – for food, relaxation, shipping or dozens of other benefits that humans get from the seas. Today, however, the problems facing the ocean rank low on the priorities for many communities: In one survey from the U.S., respondents put "the condition of the world's oceans" 10th on a list of 15 environmental issues that they were extremely or very concerned about.

These disconnects provide challenges to applied researchers like Amelia Greiner Safi, a senior research associate in the Department of Communication and faculty in the Master of Public Health Program at Cornell University in the United States. Her work focuses on the ways that people understand, and act on, information about a range of health, environmental and social problems. She is interested in translating research on communication and factors involved in behaviour change for non-academic audiences so that these findings are accessible and can inform practice and policy. In the case of the ocean, one way to possibly motivate change, she says, is to create relateable narratives about the current state and future of the watery world.

Greiner Safi will speak on a panel about fostering "ocean literacy" at an event on 9 June (https://oceanconference.un.org/index.php?page=view&type=20000&nr=2129&menu=3327) at the United Nations Ocean Conference (https://oceanconference.un.org/) in New York. This event is organised by Future Earth, the International Council for Science (ICSU) and other partners. She sat down with Future Earth's Daniel Strain to discuss how the scientific community can talk about the ocean in ways that hit home for land-dwellers.

Daniel Strain: What can we say about how much the public knows, or doesn't, about how humans are affecting the health of the ocean?

Amelia Greiner Safi: In surveys specific to oceans, people are often more concerned about the ocean than they are informed about the details of ocean problems. In a way, that's good news as getting people to care and believe there is a problem is an important hurdle for creating change. People fairly consistently have pollution, overfishing, melting sea ice and flooding at the top of the list – and there's general awareness that at least some of the problems are caused by people.

Amelia Greiner Safi. Photo: Tiiti Lukk

(/sites/default/files/images/GreinerSafi.jpg)

That said, people are not clear on exactly what human action is leading to the ocean health issue at hand. This is especially true for ocean acidification. Often even those concerned don't see their day-to-day activities as impacting the oceans. Others don't know what policies or larger-scale efforts would address the problem in question. One European survey showed that 57% of people didn't believe individual changes would improve ocean health.

There's also a lot we don't know about ocean literacy. There's disagreement about what information is important for people to know. Also, and this is huge, much of the available research on ocean knowledge or awareness focuses on more western audiences, which isn't sufficient at all for an issue as global as ocean health.

DS: Are ocean issues more complicated to communicate than the challenges facing our lands?

AGS: Human-environment challenges can be tricky to communicate, whether terrestrial- or ocean-focused, because it requires people to make indirect, or what we call "upstream," linkages. Asking people to map how their driving habits impact air quality, let alone the ocean, is challenging both for the number of steps and the science involved – even if described in the simplest of terms.

There are studies that argue that as primarily land-based creatures we are more familiar with and able to observe and discuss land-based changes. Other studies show that awareness of the ocean other than beaches – like the deep ocean – is extremely poor. Oceans are often conceived as vast, powerful, resilient. And for some, this makes accepting the concept of ocean fragility more challenging. But think the bigger issue is that for people who are concerned, they don't see their actions as impacting the ocean.

DS: The oceans can seem far away.

AGS: Right – far away in a number of ways. There's research that has addressed the problem of "psychological distance (https://mail.google.com/_/scs/mail-static/_/js/k=gmail.main.en.SrXJ9t7cW4A.O/m=pds,pdit,m_i,pdt,t/am=VsA5RO79AAcx6CwdAmHOn_nLz-Fhx2D_H_QAuSrgGvA3-3-A_wAAAAAAAAAAAAAAAAAAAAAWhSX/rt=h/d=1/rs=AHGWq9Bwvyre8rHoR5OQkZgp4hDJBPa2Fg)" and ocean health. The idea here is that the more abstract an issue is to an audience, the harder it is to inspire change. So for some, "ocean health" may be confusing in terms of what it means and may be abstract in terms of impacting "other" people somewhere else in the future. So there's a need to lessen that distance.

Depending on the audience, offering a concrete, immediate and relatable point of entry through something familiar – beaches, vacations, seafood, jobs, local economy – may be a much more viable means of talking about ocean issues than starting off with a broad concept like ocean health or ocean acidification. This isn't to minimise the scale of the problem – it's to open a door to allow for further conversation.

DS: Various groups have come up with different definitions of what should constitute "ocean literacy." Can you explain these different approaches?

AGS: People use and understand "ocean literacy" in different ways that may have little to do with the formal definitions out there. Ocean literacy was originally formally defined in the U.S. in 2004 (http://oceanservice.noaa.gov/education/literacy/ocean_literacy.pdf) as "an understanding of the ocean's influence on you and your influence on the ocean." That definition is accompanied by seven key principles and 44 concepts – and an expectation that an ocean literate person understands these concepts, can communicate meaningfully about the ocean and make informed ocean-related decisions. Associated endeavors often focused on K-12 education and engagement at aquariums.

More recently, there have been two large, multi-year ocean literacy campaigns in the European Union that expand upon the goals, means and audience – with more attention to policy and behaviour change. They are Sea Change (http://www.seachangeproject.eu/) and ResponSEAable (http://www.responseable.eu/). IOC-UNESCO also recently announced (https://oceanconference.un.org/commitments/?id=15187) a voluntary commitment of "Ocean Literacy for All" with a much more global partnership and audience. I'm interested to see how this unfolds.

DS: What are the big considerations moving forward?

AGS: I think one of the big questions to think about is what the various goals behind ocean literacy are and how well-matched the efforts are to those goals – given that we know information alone isn't usually sufficient for change. Is the goal to increase awareness? To generate connection, interest and wonder? Or to drive action now at a variety of levels that leads to conservation or more sustainable use of the seas? Those are very different goals and impact what information is important and what means of communication is most effective.

The more these efforts involve an understanding of their audiences and what might be motivating them, the better. Similarly, the more these efforts can support or make use of people serving as "science-policy intermediaries" – individuals whose role is to directly help businesses and policy-makers incorporate evidence – the easier it is to drive large scale change.

DS: What should scientists and science communicators do to get across these issues?

AGS: Well, I can offer some thoughts on what might be helpful based on work from a variety of researchers. Thinking about a way to establish a connection via emotion or a shared value, such as responsibility or protection, can be really important for getting attention, making the story relatable and accessible and possibly motivating action. There's a huge need for a solution focus. If bad news or fear-based messages about the ocean aren't coupled with a sense that people can do something about it at individual, community or policy levels, people can shut down and ignore what's going on, not bother to try or be even more resistant to making a change.

Finally, these are complicated issues, and people process information in really different ways, so it's critical to help them connect the dots through as many different media and styles as possible – through written words, spoken words, images, metaphor, simple examples and more complex ones.

DS: It seems like it's crucial to understand who we're trying reach, too.

AGS: Absolutely. I see this as understanding what means are effective to even start a conversation. There was a survey from the AP, NORC and Yale recently about different environmental attitudes (http://www.apnorc.org/PDFs/Global%20Warming/12-2015%20Segmentation%20Report_D10_DTP%20Formatted_v2b-1b.pdf), values and behaviours in the US. One of my takeaways is that there is an enormous middle ground of people that fall in between the clearly environmentally-friendly and the anti-environmental. These are important audiences to understand. It's worth remembering that many in that middle might make "environmental" decisions for reasons that have more to do with their health or that of someone they know, to save money or for religious or moral reasons, rather than overtly environmental ones.

Sometimes the behaviour in question is not easy or convenient – so this points to both individual and structural considerations. In other words, what can change to make a sustainable choice the easy one? Also, for tactics on how to frame issues for these audiences, there's been great, publicly available work on how to talk about climate change or oceans and health. FrameWorks has done excellent work around ocean communication (http://frameworksinstitute.org/climate-change-and-the-ocean.html) in particular.

DS: You've spoken about how the idea of "narrative" can be really important to getting attention and possibly inspiring change.

AGS: There's been fabulous work recently on the role of narrative and science (http://m.pnas.org/content/111/Supplement_4/13614.abstract), especially for communicating with and engaging non-experts. Narrative serves as relatable way to marry science with human experience. Narrative accounts are more digestible, easier to remember and can help crystallise both the benefits of taking action now and the costs of not. If people can remember and explain something, then they can share it – with friends, colleagues, policy-makers. That bodes well for getting and keeping an issue on the agenda amidst a sea of competing needs. If a story can help make an economic case by making the costs of inaction visible and meaningful, all the better. There was a great example of a narrative about ocean acidification (https://link.springer.com/article/10.1007/s13280-013-0442-2) from researchers in the U.S. a few years ago.

Because narratives can be so compelling, there are ethical considerations about whether the goal is to persuade or to help improve comprehension. There's also concern about how closely the specific example relates to a more general scientific principle. Is the narrative portraying something that's likely or the worst-case scenario? So as long as these considerations are actively weighed, there is exciting potential ahead

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Surveillance for Hemorrhagic Septicemia in Buffalo (Bubalus bubalis) as an Aid to Range Expansion of the Javan Rhinoceros (Rhinoceros sondaicus) in Ujung Kulon National Park, Indonesia

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Abstract

The Javan rhinoceros (Rhinoceros sondaicus) of Ujung Kulon National Park (UKNP) is the crown jewel of Indonesia's rich natural history. The park lies on a peninsula surrounded by coastline and agriculture-dominated landscapes. The invasion of water buffalo (Bubalus bubalis) into the park carries a substantial health risk to the Javan rhinoceros and threatens plans to establish a new population outside of its only current range in UKNP. Hemorrhagic septicemia (HS), known locally as septicemia epizootica and caused by Pasteurella multocida B:2, could thwart Indonesia's efforts to expand the range of the Javan rhinoceros. Because HS was considered eradicated from Banten Province, few preventative programs have been available to farmers. During June 2012–July 2013, biologic samples were collected from 770 water buffalo in 19 villages. Deep nasal swabs (n=85) were taken for bacterial culture and blood samples (n=770) were collected for serologic testing. No animals were positive on culture. The prevalence of antibody to P. multocida in this population was 1.8% (14 of 770 animals). A structured questionnaire was used to gather information about possible risk factors. Husbandry practices associated with presence of antibody in water buffalo included lack of a permanent area to house buffalo at night, low body condition score (BCS=2), high body temperature (≥40 C), a history of clinical signs or sudden death in the previous year, and a grazing system that utilized significant forage inside the park. Antibody was not associated with sex, age, vaccination status, or season. Understanding HS disease dynamics in the buffalo adjacent to UKNP may improve the livelihoods of people and health of endangered rhinoceroses in this ecosystem.

Keywords: Bubalus bubalis, hemorrhagic septicemia, Javan rhinoceros, Rhinoceros sondaicus, septicemia epizootica, Ujung Kulon National Park, Indonesia, water buffalo

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SERUM BIOCHEMISTRY REFERENCE TOOLS: NOVEL USE OF SINE WAVE FUNCTIONS TO PRODUCE SEASONALLY VARYING REFERENCE CURVES IN PLATYPUSES (ORNITHORHYNCHUS ANATINUS)

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Brucellosis Transmission between Wildlife and Livestock in the Greater Yellowstone Ecosystem: Inferences from DNA Genotyping

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HEALTH SURVEY OF FREE-RANGING RACCOONS (PROCYON LOTOR) IN CENTRAL PARK, NEW YORK, NEW YORK, USA: IMPLICATIONS FOR HUMAN AND DOMESTIC ANIMAL HEALTH

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Disturbance and mosquito diversity in the lowland tropical rainforest of central Panama

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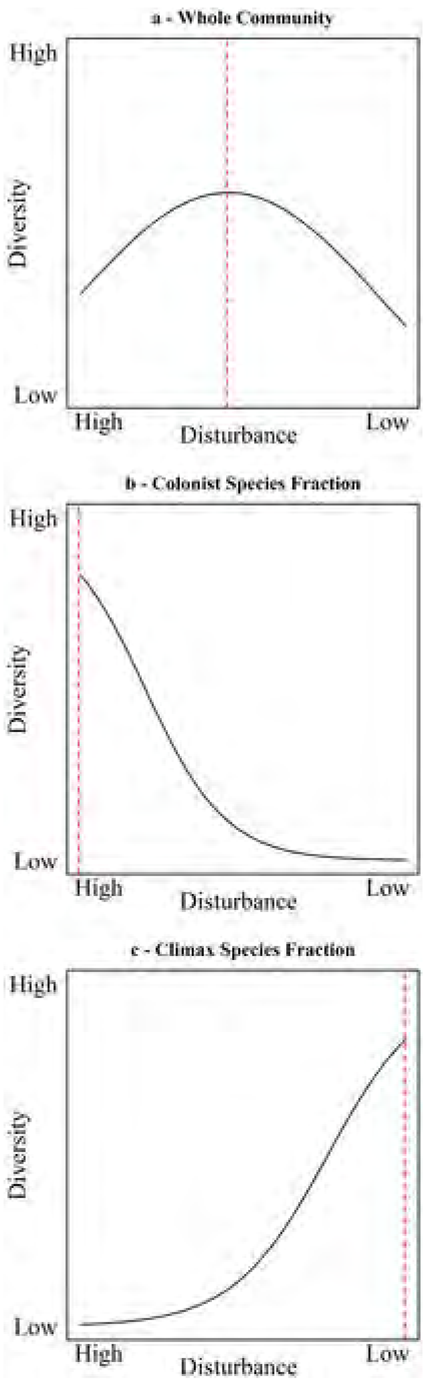
Abstract

The Intermediate Disturbance Hypothesis (IDH) is well-known in ecology providing an explanation for the role of disturbance in the coexistence of climax and colonist species. Here, we used the IDH as a framework to describe the role of forest disturbance in shaping the mosquito community structure, and to identify the ecological processes that increase the emergence of vector-borne disease. Mosquitoes were collected in central Panama at immature stages along linear transects in colonising, mixed and climax forest habitats, representing different levels of disturbance. Species were identified taxonomically and classified into functional categories (i.e., colonist, climax, disturbance-generalist, and rare). Using the Huisman-Olff-Fresco multi-model selection approach, IDH testing was done. We did not detect a unimodal relationship between species diversity and forest disturbance expected under the IDH; instead diversity peaked in old-growth forests. Habitat complexity and constraints are two mechanisms proposed to explain this alternative postulate. Moreover, colonist mosquito species were more likely to be involved in or capable of pathogen transmission than climax species. Vector species occurrence decreased notably in undisturbed forest settings. Old-growth forest conservation in tropical rainforests is therefore a highly-recommended solution for preventing new outbreaks of arboviral and parasitic diseases in anthropic environments.

Introduction

The intermediate disturbance hypothesis (IDH) is one of the most influential and well-known non-equilibrium hypotheses in ecology, providing an explanation for the role of disturbance in the coexistence of climax and colonist species[1]. The IDH postulates that species diversity is highest at intermediate levels of disturbance and declines at low and high levels of disturbance[2] (Fig. 1a). Following the development of this hypothesis[1], several studies observed ecological patterns in agreement with the non-equilibrium maintenance of biological diversity[3,4,5,6,7,8]. This support, coupled with the intuitive nature of the hypothesis, has led to its popularity and acceptance among ecologists[9]. However, recent studies have indicated weak empirical support for and logical flaws in the IDH[10,11,12,13,14], which has led to substantial debate regarding the scope of IDH and the definitions underlying it[15,16,17].

Figure 1



(**a**) The original IDH proposition made by Connell[1]. The author[1] considered diversity of a given community to be the highest at intermediate disturbance because of co-occurrence of colonist and climax species in the middle of disturbance gradient. From Connell[1] we derived theoretically that expected diversity of (**b**) Colonist species fraction peaks at high disturbance and that of (**c**) Climax species fraction peaks at low disturbance.

IDH provides an explanation for the non-equilibrium maintenance of biological diversity based on the assumption that, without disturbance, climax or disturbance-intolerant species tend to monopolise resources (e.g., space and food), driving less competitive species to local extinction and reducing overall species diversity[9]. Under high disturbance regimes, species diversity is predicted to be low because only colonist species are able to cope with severe levels of habitat degradation. Connell[1] found that vegetation in a Ugandan forest followed a successional sequence in which species richness increased during early colonising stages and then declined during late successional stages. This pattern has been referred to as the "narrow IDH definition"[16]. Huston[18] proposed an extension for this narrow definition and indicated that IDH can also apply more generally to account for disturbance-diversity relationships in non-successional scenarios in tropical rainforests. This definition has been referred to as the "broad IDH definition"[15]. According to this definition, the IDH predicts that disturbance-tolerant species (e.g., colonist) will prevail at high levels of disturbance and that these species will be competitively displaced by disturbance-intolerant species (e.g., climax) under low-disturbance regimes. The IDH also states that these two groups of species should be able to coexist at intermediate levels of disturbance, resulting in a unimodal ('hump-shaped') relationship between species diversity and disturbance intensity or frequency (Fig. 1a). Thus, disturbance can act as a reset mechanism whereby populations of competitively dominant species are either periodically subjected to disturbance or subjected to an occasional intense disturbance. As these dominant species are challenged by these disturbance events, critical resources are released for less competitive ('rare') species to use[9]. Several empirical evaluations of the IDH have observed this pattern; 46% of IDH-related studies have shown significant species diversity relationships with a unimodal shape[19]. However, the value and utility of the broad IDH definition in ecology is contentious[10,11,12,13,14]. Details about this disagreement can be found elsewhere[14,15,16].

Herein, we tested IDH expectations empirically using a species-rich assemblage of Neotropical mosquitoes (Diptera: Culicidae) in order to: (1) describe the role of forest disturbance in shaping the mosquito community structure, and (2) identify the ecological processes that increase the risk of vector-borne disease emergence. We hypothesise that mosquito species diversity will peak at intermediate levels of forest disturbance, following IDH (Fig. 1a). This pattern is expected due to an overlap of optimal habitat conditions for both colonist (Fig. 1b) and climax mosquito species (Fig. 1c) in the middle of the disturbance gradient[1].

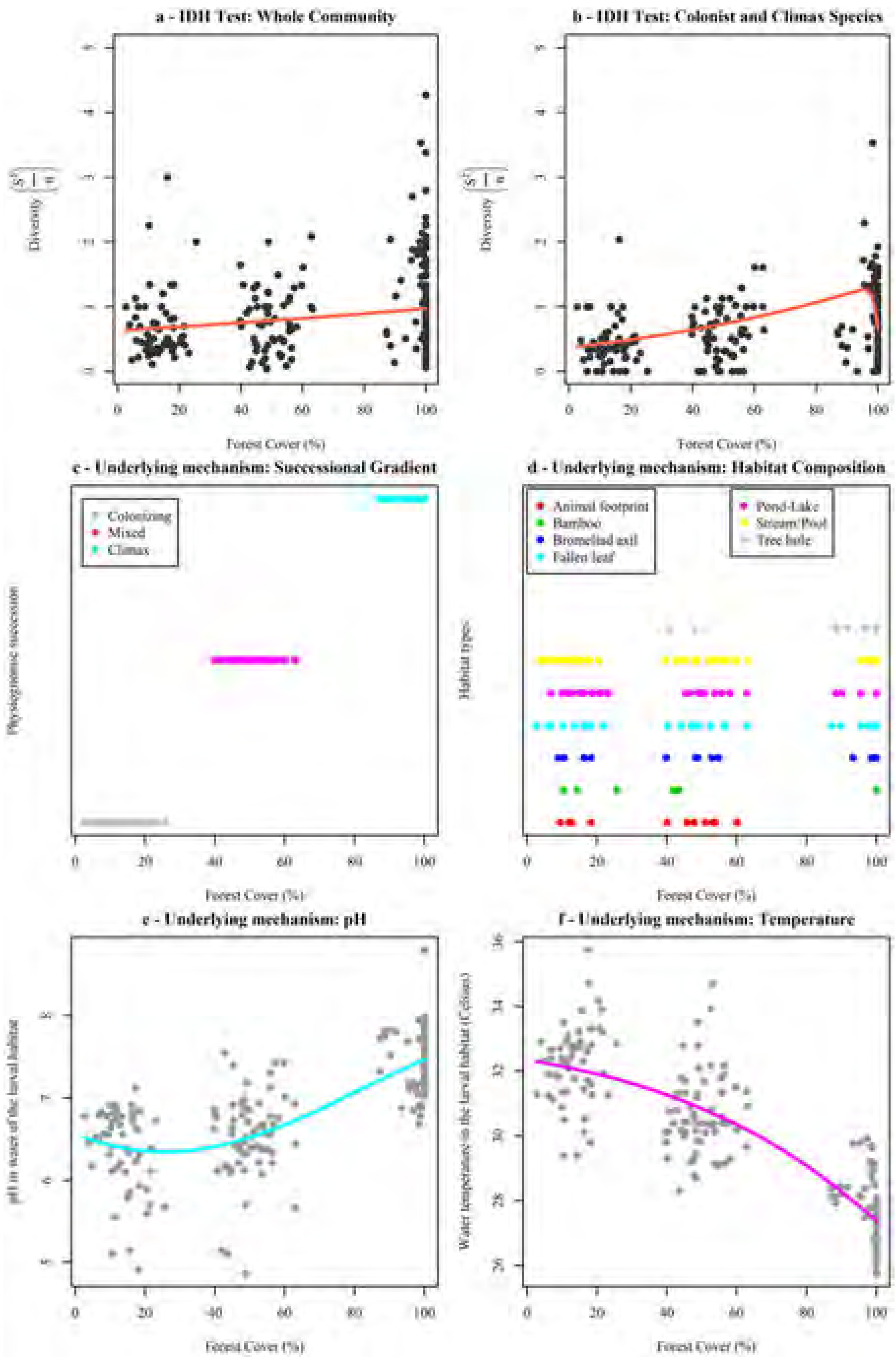
Thenceforth, as an alternative to the IDH proposal, we posit that species diversity will peak at climax forest scenarios, provided that old-growth forest habitats harbour a larger variety of larval habitats plus optimal conditions of water temperature and pH for the interaction of a larger number of species. Next, as a proposition to define the role of forest disturbance on vector-borne disease emergence, we posit that climax and colonist species vary in abundance and somewhat replace each other across a gradient of forest disturbance (e.g., species turn-over), such that within-functional group response to disturbance is more similar than between-functional group response. We also suggest that forest disturbance has a positive effect on the abundance of colonist mosquito species, because it opens opportunities in terms of larval habitat availability and conditions for this group to thrive in altered forest sites. Finally, we link these expectations to the ecological processes that might increase the risk of vector-borne disease emergence, as most colonist mosquito species are likely involved in or are capable of pathogen transmission.

Results

The role of forest disturbance in shaping mosquito community structure

We empirically tested the assumptions of IDH using 7,839 mosquito larvae belonging to 54 species that were collected from 245 larval sites. These larval habitats were either recipients/containers (natural, artificial) or ground waters. Three categories of forest cover, estimated within a radius of 150-m around each larval habitat, were observed. High forest disturbance occurred in landscape 1 – Las Pavas (2.7–25.5% forest cover), mid-forest disturbance occurred in landscape 2 – Achiote (39.8–63.1% forest cover), and low forest disturbance occurred in landscape 3 – Barro Colorado Island (87.2–100% forest cover), in central Panama. Diversity of mosquito larvae (s^2/n) varied across different categories of forest cover (%), the latter being used here as a proxy of forest disturbance (Fig. 2a,b). Nonetheless, the mid-disturbance peak (e.g., unimodal ‘hump-shaped’), expected under the IDH, was not observed, either using the whole mosquito community (i.e., colonist, climax, disturbance-generalist, and rare species) (Fig. 2a) or only Connell's fractions (i.e., colonist & climax species) (Fig. 2b). Therefore, the outcomes of our analysis using mosquito community data from central Panama do not seem to support the assumptions of IDH. Supplementary results about mosquito species classification into functional groups (colonist, climax, disturbance-intolerant, and rare species) can be found in Supplementary Info – Fig. S1.

Figure 2



IDH testing. (**a**) whole community. The best-fitting curve was more plausible than the null model (ΔAICc = 1.88; bootstrap likelihood ratio = 4:1) and meant that mosquito diversity increased as forest cover increased and vice-versa. (**b**) colonist and climax species (Connell's fractions.). The best-fitting curve was slightly more plausible than the null model (ΔAICc = 0.37; bootstrap likelihood ratio = 2.3:1). Underlying mechanisms: 1) habitat complexity, (**c**) successional gradient and (**d**) habitat composition; and 2) larval habitat constraints, **(e)** pH. The best-fitting curve was more plausible than the null model (ΔAICc = 53.2) and **(f)** temperature. The best-fitting curve was more plausible than the null model (ΔAICc = 1,006). R program-scripts and full results of multi-model selection are available upon request.

Mosquito diversity increased as forest cover increased and vice-versa. Potential underlying mechanisms for the observed effect of forest cover on mosquito species diversity are habitat complexity and habitat constraints (Fig. 2c–f).

Habitat complexity is defined here as forest structure (i.e., number of vegetation layers), which increased from low to high forest cover values (Fig. 2c). Furthermore, colonising forest scenarios were mainly composed of herbaceous stratum, whereas mixed forest scenarios were composed of two or more strata, and then climax forest scenarios were represented by old-growth forest with herbaceous, understory, canopy, and emergent layers of vegetation. Larval habitat composition and availability varied along this gradient of vegetation structural complexity (Fig. 2d). For example, the proportion of fallen leaves increased with high forest cover (11 in low, 12 in mid, 20 in high forest cover), as well as ponds (16 in low, 12 in mid, 31 in high forest cover) and stream margins (17 in low, 19 in mid, 32 in high forest cover). Tree holes were only found in habitats of high forest cover (25) and mid-forest cover (2). Animal footprints were observed in low to mid-forest cover habitats (4 and 8, respectively), but none were observed in high forest cover habitats. Four bromeliads were found at low forest cover, 8 at mid-forest cover, and 16 at high forest cover habitats. Bamboo trees were observed equally in all forest cover habitat categories (3 in low, 3 in mid, 2 in high forest cover).

Habitat constraints, water temperature and pH, measured during the time of mosquito collection in each sampling habitat, varied across the gradient of forest cover (Fig. 2e,f). Values of pH increased with forest cover, and for this reason, acidic water was found more frequently in low forest cover larval habitats (Fig. 2e). Water temperature decreased when forest cover increased. For this reason, sunlight-exposed waters were more frequently found in low forest cover sampling habitats (Fig. 2f).

The ecological processes that might increase the risk of vector-borne disease emergence

We investigated a possible association between mosquito functional classification and vector status using colonist and climax species, which were the most abundant groups in our study. Evidence of vector incrimination for these species in the Republic of Panama or, if not available, in the Neotropical Region are shown in Supplementary info – Table S1. Out of 10 colonists, 8 were considered vectors of important pathogens[20,21,22,23,24,25,26,27,28,29,30]. *Anopheles albimanus*, *Cq. venezuelensis*, *Cx. coronator*, *Cx. nigripalpus*, *Cx. pedroi*, *Ma. titillans*, *Ps. cingulata*, and *Ps. fexox* showed evidence of natural infection in the field and/or high vector competence in the laboratory. Whereas *An. albimanus* was mentioned as a main vector for malaria parasites in Central America, the other species were listed as vectors for arboviral pathogens that can infect human and/or domestic animals in that region. *Coquillettidia nigricans* and *Cx. declarator* were the only non-vector colonist species of the group. On the other hand, climax species with vector incrimination in the literature were: *Ad. squamipennis*, *An. oswaldoi*, *An. triannulatus*, and *Li. durhamii*[21, 22, 31,32,33,34,35,36,37,38,39,40,41,42]. *Aedeomyia squamipennis* was considered a vector of enzootic cycles, as it can transmit avian malaria parasites and the Gamboa virus. Both *Anopheles oswaldoi* and *An. triannulatus* were considered auxiliary vectors of *Plasmodium*. A mechanical vector role was considered for *Li. durhamii*, as this species could carry eggs of the human botfly.

The other 8 climax species did not have evidence showing that they could vector pathogens to humans or wildlife, so they were classified as non-vectors. We investigated the most recent reports of vector incrimination for the species in the colonist and climax groupings to avoid temporal bias due to past incriminations that do not hold currently. By applying this strategy, we found that 8 out of 10 colonist mosquito species were incriminated as vectors of pathogens to humans or animals, and 4 out of 12 in the climax fraction. A significant effect (X^2 test statistic = 4.791, p-value = 0.029) for the association between mosquito functional classification (i.e., colonist or climax species) and vector status (i.e., vectors or non-vectors of pathogens) was found (Table 1). This means that the number of vector species was higher in the colonist category whereas more non-vector mosquito species fit into the climax category. Alternatively, our findings could also mean that vector species were more likely to be colonist than climax mosquito species, while the opposite is also true for non-vector species.

Table 1: Association of Vector Status (yes, no) with Community Fraction Type (colonist, climax) in a contingency 2by2 table.

Discussion

Does mosquito species diversity peak at intermediate levels of forest disturbance (Connell's IDH model *vs* Fox's criticism)?

In contrast with several previous studies that found patterns supporting the non-equilibrium maintenance of biological diversity[3,4,5,6,7,8], Fox[14] challenged Connell's[1] IDH model, citing a lack of theoretical support. Connell[1] stated that at intermediate disturbance levels, competitive exclusion declines, allowing for stable coexistence in a non-equilibrium state. Huston[18] simulated a Lotka-Volterra competition model with mortality events that mimicked the effects of disturbance and supported Connell's ideas. However, Fox[14] first cited the lack of evidence that supports competitive exclusion. Fox[14] also argued that the Huston[18] model has a subtle outcome. Over the long-term, the increase in average mortality rates cannot produce stable coexistence.

In agreement with the current scientific proposals challenging IDH[11,12,13], we did not find a hump-shaped diversity-disturbance relationship using mosquito larvae diversity and forest cover percentage from the lowland tropical rainforest of central Panama. The present test therefore failed to empirically support IDH. Notwithstanding, the main claims of Fox[14] pointed to logical flaws in the theoretical rationale of IDH: 1) lack of evidence of competitive displacement, 2) not all species have linear responses to disturbance, and 3) increase in average mortality rates in the long-term, are discussed herein, as follows.

The present study found Connell[1] fractions - colonist and climax species. Colonist mosquito species were associated with low forest covers at one extreme of forest disturbance gradient, whereas climax species were found at the opposite end. This result resembles the mechanism of coexistence of closely related species at the landscape scale (although they can be spatially segregated at the habitat scale), proposed by Laporta and Sallum[43], after Juliano[44].

Similarly, it is shown here that colonist *An. albimanus* did not co-occur with two climax species, *An. oswaldoi* and *An. triannulatus*, at the habitat scale (i.e., larval habitat); although the species coexisted at the landscape scale. It is interesting to note further that both *An. oswaldoi* and *An. triannulatus* co-occurred at the larval habitat, but their abundances (n = 278 and n = 138, respectively) were lower than that of *An. albimanus* (n = 602). This may indicate that *An. oswaldoi* and *An. triannulatus* interact at the microhabitat scale[43], so that they need to share resources at the surface of the water on those larval habitats where they co-exist (e.g., ponds and stream margins). The partitioning of resources between *An. oswaldoi* and *An. triannulatus* is likely due to favourable water pH and temperature conditions in shared larval habitats with high forest cover. However, when this high forest cover setting is disturbed, departing from 100% to 20%, it is plausible to assume that both *An. oswaldoi* and *An. triannulatus* (i.e., climax) get displaced[45] by *An. albimanus* (i.e., colonist), an abundant species in colonising disturbed areas[46, 47]. An illustration of the possible competitive displacement of *An. albimanus* and *An. oswaldoi*/*An. triannulatus* mediated by disturbance was made herein.

Another group of closely related species is made up by the colonists *Cx. coronator*, *Cx. declarator*, and *Cx. nigripalpus*, with *Cx. interrogator*, another climax species of the same subgenus. These *Culex* species also showed co-occurrence at the landscape scale and, potentially, competitive displacement. The competitive displacement could occur when an assemblage dominated by *Cx. interrogator* in high forest cover sites is subjected to disturbance and gets replaced by other dominant *Culex* (*Cux.*) species in open areas.

Only 7 species (3 *Anopheles*, 4 *Culex* (*Cux.*)) out of 22 colonist and climax species in our dataset fit with a pattern of competitive displacement. This is partly because semi-permanent water habitats species (i.e., *Coquillettidia*, *Mansonia*, and *Psorophora*) mainly occurred in disturbed areas, whereas tree hole and fallen leaves species (i.e., *Ae. terrens*, *An. eiseni*, *Li. asulleptus*, *Li. durhamii*, *Tr. digitatum*) were mostly found in forested sites.

For these latter species (e.g., *Ae. terrens*), a disturbance event cannot produce another pair of coexisting species, because tree holes were absent in low forest cover. In relation to the first claim of Fox[14] regarding lack of evidence for competitive displacement, we state that we could find evidence of competitive displacement, but it does not seem to have a large effect.

Fox[14] also claimed that not all species have linear responses to disturbance. This claim was supported by our outcomes. Highly abundant species in colonist and climax fractions were found. These species had a linear response to the disturbance gradient. For instance, *An. albimanus*, *Cx. coronator*, *Ps. cingulata*, and *Cq. nigricans* had peak abundance in the most disturbed areas, and this peak declined towards zero abundance in high forest cover sites. Similarly, *Ad. squamipennis*, *Ae. terrens*, *An. eiseni*, *An. trianullatus*, and *Ur. geometrica* had very sharp responses on larval habitats with high forest cover, while their abundances were zero at the other extreme. Notwithstanding, there were other species that did not respond linearly to the disturbance gradient, as claimed by Fox[14]. The colonist *Ma. titillans* had one peak of high abundance at low forest cover, which is supported by the study of Alfonzo *et al.*[42], and another with mid-abundance in the middle of the gradient. The climax species *Li. durhamii* had two peaks as well, a very high one at high forest cover, supported by Suaza-Vasco[41], and another with low abundance at intermediate/low forest cover. Additionally, we found five species that can be considered disturbance-generalists, because they had at least two peaks of equal abundances in different forest disturbance categories. This was noticed before for *Cx. erraticus* by Alfonzo *et al.*[42], where they collected 75% of specimens in open areas and 25%, in tall undisturbed forest habitats. Finally, we also found a mid-disturbance species, *Wy. simsi*, which had a peak of abundance at the intermediate portion of forest disturbance gradient. The finding of a mid-disturbance species in our dataset is interesting because it means that a community dominated by mid-disturbance species would naturally lead to the expected unimodal diversity-disturbance relationship. Considering specific attributes that enabled species to persist at any given disturbance frequency (e.g., refs 48, 49), our data could support the second claim of Fox[14].

The third claim of Fox[14] was that disturbance could increase the average mortality rates in the long-term for rare species. The author simulated from a series of population-based differential equations that species with low abundance (rare) were very likely to become extinct in places exposed to frequent disturbances in the long-term. This claim was supported by our data in full. Twenty-six (48%) of 54 species in our dataset were classified as rare species. Each of these species persists in disturbed areas in a source-sink population dynamics kind of fashion, with Barro Colorado Island as the source of their populations and surrounding areas such as PVAS and ACH as the sink, according to MacArthur and Wilson[50]. Hypothetically, if Barro Colorado Island is exposed to frequent disturbance events, these rare species would probably become locally extinct in the long-term, unless another source for their populations appears.

The fact that we could not empirically support Connell's[1] IDH pattern with our dataset is related to the claims of Fox[14]. Competitive displacement did not seem to have a large effect. Species had too many peculiar responses to the disturbance gradient, including a group of disturbance-generalists and one mid-disturbance species. In addition, the high number of rare species indicates that they would not coexist in the long-term in a scenario exposed to constant disturbances, because they would probably become extinct.

Mosquito species diversity increased towards relatively undisturbed forest environments

We rejected IDH because mosquito species diversity increased with increasing values of forest cover, rather than peaking in the middle of the forest disturbance gradient. Our results depicted an effect of forest cover on mosquito species diversity, meaning that the number of species increased towards healthier and relatively undisturbed forest sites. Although positive and statistically significant, this effect was small. One analogous example of such a small effect is: an increase of 0 to 50% forest cover would increase species diversity by 0.2. However, all 26-rare species (48% of the whole community) were more frequently found in high forest cover.

Underlying mechanisms that could support higher species diversity at high forest cover settings might be habitat complexity and habitat constraints. The former relates to vegetation complexity, which determines the availability and spectrum of different types of larval habitats, whereas the latter is related to chemical composition of the water (i.e., temperature and pH) in those habitats. Vegetation complexity tends to decrease from climax to colonising forest scenarios[51], thus supporting fewer mosquito species along the disturbance axis due to fewer opportunities to develop and coexist. In contrast, habitat constraints tend to increase in the same direction making it harder for climax and rare species to survive in harsh environments[51]. Fluctuations of habitat complexity and constraints lead to variation in larval habitat properties that are more evident at the opposite extremes of the disturbance gradient.

Moreover, higher habitat complexity in undisrupted forest environments might promote niche differentiation due to a higher variety of larval habitats[51], while lower habitat constraints in these settings may also favour optimum values of temperatures and pH to yield a larger number of interacting species as larvae in shared aquatic habitats[52]. Our findings further suggest that habitat complexity and constraints are shaped by a successional gradient of forest physiognomic stages, translated into different habitat conditions under three discrete categories of forest cover. Differences in mosquito diversity and abundances across a gradient of forest disturbance could be explained by shifting ecological conditions that affect larval breeding site availability and quality.

Limitations of the study

The limitations of the present study can be divided into three categories. Ideally, the best study design would match characteristics to cope with these three limitations: (1) The gradient of forest disturbance in this study was not continuous. We had three categories of forest disturbance: a) low forest cover (PVAS), b) medium forest cover (ACH), and c) high forest cover (BCI). In each category, there was a gradient of forest cover, but data were lacking in-between categories. Having more data to fulfil these gaps could help to have a more accurate picture of the effect of forest disturbance on mosquito diversity. (2) Our study design was not a follow-up of successional stages in a single landscape. As our study was a cross-sectional one, the major assumption is that BCI is an undisturbed scenario for ACH (a mid-disturbance scenario) and PVAS (a high-disturbance scenario). During the study design, these areas were selected in the same ecosystem (lowland tropical rainforest), so that they could hypothetically represent the same temporal process of disturbance. Using a cross-sectional study to test a temporal-dependent phenomenon such as the successional stages of Connell's[1] IDH is not only challenging, but this was the main critique of Sheil and Burslem[15], when they replied to the "IDH should be abandoned" by Fox[14]. According to these authors, replacing space-for-time in such a case would not give the same evidence that Connell[1] found in successional stages of forest in Uganda. This critique made Fox[16] lower the tone of his statements and agree with the importance of the narrow Connell-based definition of IDH in order to avoid confounding factors. (3) Our study did not experimentally test the effects of forest disturbance on mosquito diversity. It is not trivial to propose an experiment with an intervention such as 'forest disturbance'. Despite the importance of such an experiment, the opportunities to accomplish this can be very scant. Nevertheless, in places where forest disturbance is out of control, such as in the Brazilian Amazon[53], one type of intervention could be to compensate landowners for keeping their forest in good shape, and track changes in the mosquito community over time with nearby territories in which landowners would not receive any bonus.

The ecological process that make risky scenarios for vector-borne disease emergence

While it is true that our results did not provide empirical support for IDH in the field of ecology, using this hypothesis and the criticism around it (i.e., by Fox[14]), as a framework, allowed us to better understand the role of forest disturbance in mosquito-borne disease transmission. Our considerations here also have implications for disease prevention and control. For instance, Lounibos[45] discussed the applications of competitive displacement as practice for targeting vector population reduction. Our outcomes suggest that competitive displacement could be applied in the Republic of Panama as well as more broadly (i.e., Colombia, Peru, and Central America)[20, 21, 46, 47] to prevent malaria epidemics. This can be achieved by increasing forest cover recovery in highly disturbed areas (i.e., PVAS and ACH), favouring the likelihood of auxiliary malarial vectors (i.e., *An. oswaldoi*/*An. triannulatus*)[36, 37] over primary ones (i.e., *An. albimanus*). This control scheme might also be applied to prevent epidemics of arboviral pathogens involving colonists (i.e., *Cx. coronator*, *Cx. declarator*, and *Cx. nigripalpus*) and climax species (i.e., *Cx. interrogator*) within the subgenus *Culex* of *Culex*.

In terms of disease transmission[54,55,56], focusing on Connell's fractions (e.g., climax and colonist mosquito species) gave us the opportunity to investigate the role of these assemblages on disease emergence in relation to forest disturbance. Changes in biodiversity caused by recent landscape disturbance in Panama, or in any other place of the tropical rainforest domain[57], are likely to impact vector species spectra and status over time[58, 59]. We found that the number of mosquito species being incriminated as vectors of pathogens was significantly higher in the colonist fraction than in the climax fraction. Not only was the association colonist–vector species significant, but also it was the most prominent at highly disturbed forest sites, while its likelihood decreased notably towards relatively undisturbed forest settings.

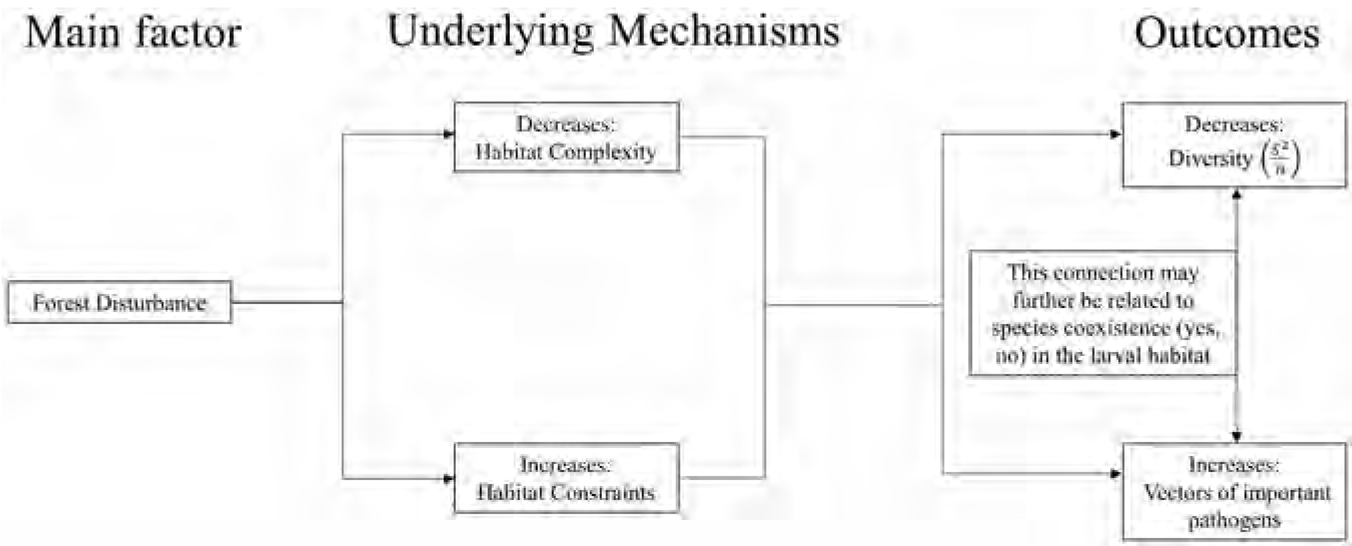
A positive linear response by colonist–vector species to forest disturbance seems to be a tangible process that might increase disease transmission risk in forest-altered tropical areas[58]. '*The colonist–vector fraction*' including the malaria vector (i.e., *Anopheles albimanus*) and zoonotic and bridge vectors of several arboviruses (i.e., *Culex pedroi*, *Culex nigripalpus*, *Psorophora cingulata*, *Psorophora ferox*, *Mansonia titillans*, and *Coquillettidia venezuelensis*) increased in abundance as a function of forest disturbance. According to this view, the so-called spill-over effect might not be a random process, but rather a consequence of forest degradation leading to a higher probability of contact between colonist–vector mosquito species and humans at forest-altered sites. The proportion of different reservoir/hosts existing in forest degraded areas of Panama, will then determine the ultimate disease outcome there, as most mosquito species in forest-altered sites tend to feed opportunistically and upon what is most available nearby. All together, these results suggest a likely role of forest disturbance into vector-borne disease emergence in recently disturbed tropical regions[58, 59], including Panama.

Nevertheless, considering the well-known suite of entomological studies by Dr. Pedro Galindo in the Republic of Panama[54,55,56], just to mention a few, and more recently the theoretical insights by Randolph and Dobson[60], finding vector species in the colonist and climax fractions should be equally expected. This is theoretically anticipated because female mosquitoes of any particular species have the same opportunities to blood-feed upon vertebrate animals that harbour pathogens. This argument might sound compelling, but it has not been supported by prior studies on vector competence. For instance, Turell by himself[26] and with colleagues[24, 28, 30] experimentally tested many mosquito species, thought to be competent transmitters, for infection with different arboviral pathogens, but only partial results could be translated into information on vector incrimination. Cohuet *et al.*[61] further stated that pathogens could shape vectors.

If it were true that all mosquito species in the community could transmit pathogens equally efficiently, why are those in the colonist fraction of our study more likely to do so? On the one hand, we could rely upon the work of Myers and Patz[58], who stated that forest disturbance selects the most abundant species, which could lead to higher contact rates with domestic animals and humans, thus increasing the odds of pathogen transmission on these hosts. On the other hand, we should also consider random genetic processes (e.g., neutral effects[62]) as a mechanism that could enhance vector potential at any given time-space. For example, a single mutation event made *Ae. albopictus* a superior vector of Chikungunya virus during several outbreaks across Asia and Europe, ten years ago[63].

Considering the hypothetical synthesis of our work (Fig. 3), a logical statement is that forest disturbance could cause the overall decline of mosquito species diversity, yet at the same time, it could increase disease transmission risk. Although we did not measure disease risk directly, high abundance of colonist–vector species at immature stages was applied here as a proxy for female mosquito population size in forest altered sites. According to this, the deduction would be that one possible mechanism of interconnection of diversity-disease might be related to species interactions in the larval habitat. The authors are conscious of the limitations of the present work, and so the synthetic diagram in Fig. 3 is only intended to guide future research efforts in this direction.

Figure 3



Theoretical synthesis of the results obtained in the present work. The main factor, forest disturbance, decreases habitat complexity and increases habitat constraints. These underlying mechanisms decrease diversity and increase vectors of important pathogens.

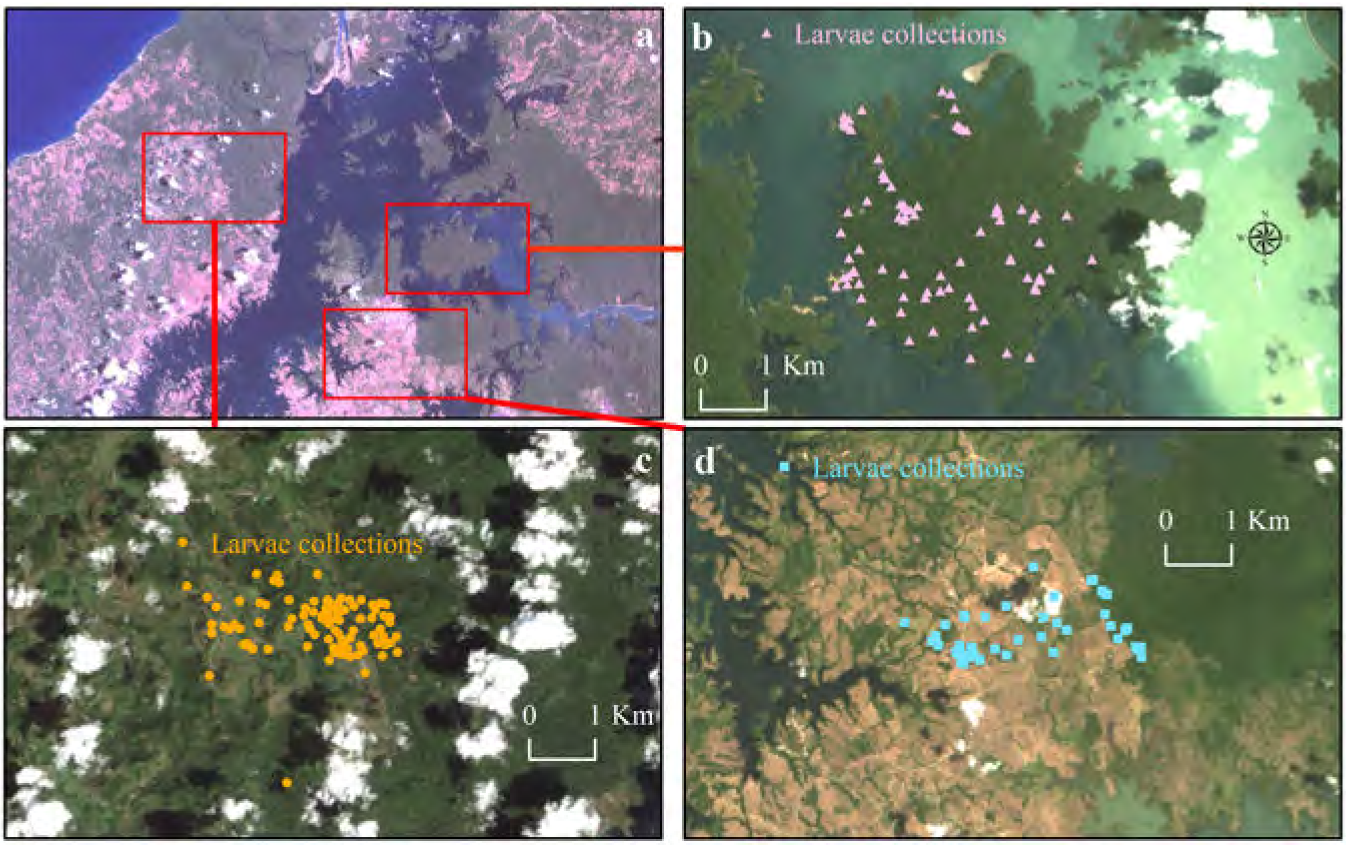
Randolph and Dobson[60] made a strong critique about the likely effects of high biodiversity as the buffering element to prevent the emergence of vector-borne disease in relatively undisturbed forest habitats. In our study, colonist–vector species such as *An. albimanus* (main vector of malaria in Central America[20, 21, 46, 47]), *Cx. nigripalpus* (main vector of St. Louis Encephalitis Virus in the US[26]), and *Cx. pedroi* (main vector of the Eastern Equine Encephalitis Virus in Peru[27]) were conspicuous in highly altered forest settings, while their abundances were almost zero at relatively undisturbed forest sites (i.e., old-growth forest). The fundamental conclusion derived from the field of disease ecology is therefore that old-growth forest conservation in tropical rainforests is a reasonable and highly recommended solution for preventing new outbreaks of arboviral and parasitic diseases in anthropic environments.

Methods

Study system

This was a cross-sectional and a space-for-time study conducted in the lowland tropical rainforest of central Panama. Herein, we selected three landscapes at different successional stages containing mostly lowland forest and wetland ecosystems[64] (Fig. 4a). Historically, this area included the Former Panama Canal Zone, a US military territory, with a highly-characterised mosquito fauna due to systematic sampling during the 20th century[65]. Walter Reed Biosystematics Unit (WRBU) Mosquito Catalog[66] and in-country sources have recorded 286 species of Culicidae in Panama.

Figure 4



(**a**) The lowland tropical rainforest of Central Panama, 2000. (**b**) The Barro Colorado Island, 2014. (**c**) Achiote, 2016. (**d**) Las Pavas, 2014. Source: Landsat imagery courtesy of NASA Goddard Space Flight Center and U.S. Geological Survey.

Three areas, each expected to having low, medium and high forest disturbances were selected in central Panama for mosquito larvae collection: Barro Colorado Island - BCI (9° 16′ N, - 79° 84′ W; Fig. 4b), Achiote - ACH (9° 22′ N, - 80° 02′ W; Fig. 4c) and Las Pavas -

PVAS (9° 09′ N, - 79° 87′ W; Fig. 4d). These areas (herein BCI, ACH, and PVAS) have different climatic conditions due to their geographic position along a Pacific-Atlantic rainfall gradient[67]. BCI and PVAS are positioned closer to the Pacific Ocean; they are drier (1,793 mm of annual rainfall) and more seasonal, experiencing 7 to 8 months of wet season and 4 to 5 months of dry season. In contrast, ACH is situated closer to Isthmus' Caribbean coast; it is more humid (3,300 mm of annual rainfall) and less seasonal, experiencing year-round precipitation and lacking a well-defined dry season[64, 68].

Barro Colorado Island (Fig. 4b) is a National Reserve under the custody of the Smithsonian Tropical Research Institute (STRI) since 1923, and is protected by the environmental laws of Panama. The island has a research facility inhabited by a small group of scientists, visitors and administrative personnel, but most of its territory is unoccupied and consists of undisturbed old-growth forest. Hubbell[62] and colleagues working in BCI proposed the Unified Neutral Theory of Biodiversity, using data collected on plant species abundances.

PVAS and ACH, conversely, are human-altered forest environments that have been gradually colonised during the last 60 years; they have roughly the same number of people, and thus intensity of forest disturbance over these years is thought to be similar. Because of the aforementioned climatic differences between PVAS and ACH, it seems that the latter is more resilient to disturbance because of the higher annual rainfall. This difference can be checked by comparing the satellite imagery taken from the landscape of ACH that shows a later stage of succession (Fig. 4c) in comparison with that observed for PVAS, which resembles an early stage of colonisation (Fig. 4d). Both ACH and PVAS are situated close to a National Park (Fig. 4a); the former borders the Gigante Forest Reserve, whilst the latter borders the San Lorenzo National Park. These landscapes include fragments of old-growth and second-growth forest intermingling with agriculture fields, cattle pastures, and human settlements. The main notion is therefore that they represent a proxy for a hypothetical disturbance scenario of BCI.

Mosquito sampling and species identification

Immature stages of mosquitoes were collected in linear transects (25 to 30 per each sampling area) of up to 3.5 kilometres (km) long at BCI (mean length 2.88 ± 0.31), PVAS

(3.36 ± 0.14) and ACH (3.37 ± 0.14). All mosquito-breeding sites including phytotelmata and ground water sources encountered at 3-m left and right off transects and 2-m of height were checked for the presence of larvae and pupae. Ground water sources were surveyed using a standard larval dipper (350 ml, 13 cm diameter per unit) (BioQuip®, Rancho Dominguez, CA). Up to 40 dips (140,000 ml approx.) were taken from each breeding site after ten initial dips to determine positivity. Roots of aquatic vegetation (i.e., mostly *Pistia* and *Eichornia*) in stable breeding sites were rinsed with a 10% solution of Sodium Hydroxide, so that larvae and pupae of *Mansonia* and *Coquillettidia* mosquitoes detached themselves and rose to the surface. Furthermore, Phytotelmata breeding sites were surveyed using a 250 ml pipette and a white plastic tray (25 × 20 × 4 cm) (BioQuip®, Rancho Dominguez, CA), with relatively similar amounts of water being extracted as in-ground breeding sites. Samples were placed into Whirl-Pak® plastic bags (118 ml, 8 × 18 cm) (BioQuip®, Rancho Dominguez, CA) filled approximately 3/4 full of water from their respective habitats and brought to the laboratory in a cooler container. Later, they were sorted to subfamily level, grouped according to instar in different breeding chambers and link-reared to adult.

Each larval breeding site was photographed with a digital camera and characterised according to environmental features using a standard data collection form[66]. This form included a set of discrete and continuous environmental variables, including degree of shade, water stability, presence or absence of vegetation as well as pH and temperature (°C) of the water, respectively. Water pH and water temperature were measured with a high range HI 98130 Waterproof pH/Conductivity/TDS Tester (Hanna® instruments, Woonsocket, RI). In addition, geographic coordinates (e.g., values of latitude and longitude) for each larval sampling site were recorded using a hand held Global Positioning System (GPS) unit (Garmin® International, Olathe, KS), set to the WGS84 datum and geo-referenced in a Landsat™ 8 OLI satellite image[69]. The bands Red (B4), Green (B3), and Blue (B2) were used to make a RGB composition that was pan-sharpened with the multispectral band (B8) in ArcMAP™ 10.3.1 (ESRI, Redlands, CA), resulting in a 15-m spatial resolution image above which geo-referenced coordinates were represented. This allowed us to estimate the percentage of forest cover within a 150-metre radius around each sampling unit (i.e., larval sampling sites). Sampling transects in PVAS and ACH encompassed areas of low (e.g., >35%), intermediate (e.g., >35% and <65%)

and high forest cover (e.g., >65%) in similar proportions, while BCI comprised high forest cover points (e.g., old-growth forest). Mosquito larval collections were carried out every other month from August 2011 to November 2012 in BCI; sampling in PVAS and ACH was conducted in the same fashion from May 2012 to January 2013. A representative portion of the data sets analysed in the present work can be obtained by request from the *VectorMap* portal[70].

Reared adult mosquito samples were pinned in cardboard triangles, labelled with a unique code/number, and identified using diagnostic morphological characters[71,72,73]. Species verification was achieved using male genitalia and fourth-instar larval skin preparations following the protocols listed by Thomas Gaffigan and James Pecor[66]. Voucher specimens were deposited at INDICASAT AIP, and also at the University of Panama. In addition, two legs were removed from well-preserved specimens for molecular species confirmation and analysis using the Barcoding region (5′ prime region of the Cytochrome C Oxidase Subunit One mitochondrial gene [CO1])[74]. A total of 289 samples for 52 species, initially identified on morphological characters, were randomly taken from the total collected and processed molecularly to rule out potential confounding effects of morphology on the estimation of species diversity. DNA extraction, PCR-amplification and sequencing were done at STRI following standard protocols[75]. We built a neighbour-joining (NJ) tree using CO1 sequences in MEGA v.5.1[76] with Kimura 2 parameter (K2P) distances, and bootstrapped the topology with 500 replicates to obtain branch support. We also created a NJ tree using an expanded dataset combining our CO1 sequences along with additional CO1 sequences from GenBank[77] and from The Barcode of Life Data System (bold)[74].

Data analysis strategy

The sampling unit in the analysis was the larval habitat or larval sampling sites and for each analysis the sample size used was N = 245, which corresponded to the total number of sample sites from BCI (99), PVAS (46), and ACH (100). The strategy of combining data was three-fold: (1) in relation to the experimental design, which considered a wide range of forest cover values, and then all the sites sampled belonged to a gradient of disturbance, (2) pooling the data resulted in the same outcomes when analysing data from PVAS and ACH separately, and (3) pooled samples from PVAS, ACH and BCI allowed us to increase statistical power of each analysis and to detect deviations from randomness, making possible generalisations about central Panama including pristine and heterogeneous landscapes.

Mosquito species classification into functional fractions and IDH testing

Each mosquito species in the community was classified as colonist, climax, disturbance-generalist or rare, by employing a multi-model selection analysis for each species' specific-abundance and forest cover. This resulted in a total of 7 * 54 = 378 models. For the sake of simplicity, we did not show herein all the AICc difference and bootstrap model checking results. Notwithstanding, all these results can be made available upon request.

We first classified mosquito species into distinct functional groups, following Connell[1]. This was done by examining mosquito species-specific abundance response to different levels of forest disturbance, measured by variations in forest cover proportion (%). As a result of this, we divided the mosquito assemblage into colonist (i.e., disturbance-tolerant; Fig. 1b) or climax (i.e., disturbance-intolerant; Fig. 1c) groupings. Furthermore, species that did not respond to disturbance were classified as disturbance-generalists, and species with low abundance (<5% of occurrence) were classified as rare species.

This classification was performed by using the same approach applied by Laporta and Sallum[43]. A multi-model selection scheme was used to fit a specific regression curve to the following data: larval abundance of a given mosquito species gathered from habitats with different proportions of forest cover. Huisman-Olff-Fresco models with extensions compete against each other during this multi-model selection approach (Supplementary Info – Fig. S2)[78]. Model 1 is the null model (the null hypothesis). Models 2–7 are the alternative hypotheses. Model 2 and Model 3 indicate that larval abundance correlates monotonically (i.e., linearly) with forest cover values. Model 4 and Model 5 indicate that larval abundance has a unimodal correlation with forest cover, while Models 6 and 7 indicate that larval abundance has a bimodal correlation with forest cover. The best curve was selected based on a specific set of criteria. The selected model was based on maximum likelihood estimates and the least number of parameters, i.e., the Akaike

Information Criteria corrected for small samples (AICc)[78]. Bootstrap model checking was performed to evaluate the robustness of each selected model simulated 100 times[78].

We tested IDH assumptions by running the same multi-model selection scheme used formerly (Supplementary Info – Fig. S2). This time, the expectation was that estimates of mosquito diversity in response to different levels of forest disturbance would fit the regression curve in Model 4, thus supporting the expected outcome of IDH (i.e., 'hump-shaped'). First, we tried to fit data from the whole mosquito community to Model 4, and then, we fit data to the same model, but only from the two fractions proposed by Connell[1]. Forest cover was the independent variable and mosquito diversity, the dependent variable. These variables were measured at the scale of the larval habitat, i.e., the micro-habitat scale[43]. In each larval habitat, we estimated the α-diversity[79], herein referred to as diversity. The estimation of diversity followed the procedures adopted by Gotelli and Colwell[80]. The richness of species can increase because of the total abundance, so an adjustment is necessary, named rarefaction[80]. To our data, we applied this idea and then used the squared richness divided by total abundance in each larval habitat.

Causative mechanisms of ecological and epidemiological outcomes

Underlying mechanisms or possible co-factors that go along with forest disturbance and could therefore be related to the observed pattern of mosquito diversity were also assessed here. These co-factors were: 1) successional gradient of forest types, 2) larval habitat types, 3) water pH and 4) water temperature. All these co-factors were assessed in each larval habitat. Successional gradient of forest and larval habitat types were associated with forest cover variations utilising standard summarising statistics and graphics. Correlations between larval water pH and forest cover and larval water temperature and forest cover were assessed by applying the multi-model (Supplementary Info – Fig. S2) selection approach described earlier.

The vector status of each of the colonist and climax species was investigated by searching the specialised recent literature in Pubmed (5 years or more). We tried, when available, to select evidence in published papers in the last five years to decrease temporal bias. The selection was based on evidence of vector incrimination from either natural infection in field studies or vector competence in laboratory assays. Ecological studies that aimed to understand the vector role in vector-borne disease dynamics were also considered, when the authors discussed the specific role as vector for the studied species. Evidence with a low connection to vector role was not considered. For instance, a species that was positive for arboviral infection in the laboratory, but only one specimen was infected out of 30 tested was not considered a vector. Another species that was found naturally infected with non-infectious stage of a known human pathogen or with the infectious stage of a non-vertebrate pathogen was not considered a vector. An important pathogen was defined herein as any protozoa, microfilaria, and/or arbovirus that could cause clinical infection in a host, either human or animal.

The association between colonist/climax and vector/non-vector was performed by employing a 2 by 2 contingency table. We estimated the odds ratio (OR) with a 95% confidence interval, in which the null hypothesis is OR = 1 (null effect). A X^2 test was also performed to test the following null hypothesis: H_0, there is no association. The significance level adopted was 0.05.

Additional Information

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References

1. Connell, J. H. Diversity in tropical rain forests and coral reefs. *Science* **199**, 1302–1309 (1978).

2. Molino, J. F. & Sabatier, D. Tree diversity in tropical rain forests: a validation of the intermediate disturbance hypothesis. *Science* **294**, 1702 (2001).

3. Hutchinson, G. E. The paradox of the plankton. *Am. Nat.* **95**, 137–145 (1961).

4. Dayton, P. K. Competition, disturbance, and community organization: the provision and subsequent utilization of space in a rocky intertidal community. *Ecol. Monogr.* **41**, 351–389 (1971).

5. Wiens, J. A. On competition and variable environments. *Am. Sci.* **65**, 590–607 (1977).

6. Sousa, W. P. The role of disturbance in natural communities. *Annu. Rev. Ecol. Syst.* **15**, 353–391 (1984).

7. Kneidel, K. A. Competition and disturbance in communities of carrion-breeding Diptera. *J. Am Ecol.* **53**, 849–865 (1984).

8. Townsend, C. R., Scarsbrook, M. R. & Dolédec, S. The intermediate disturbance hypothesis, refugia, and biodiversity in streams. *Limnol. Oceanogr.* **42**, 938–949 (1997).

9. Sheil, D. & Burslem, D. F. R. P. Disturbing hypotheses in tropical forests. *Trends Ecol. Evol.* **18**, 18–26 (2003).

10. Hubbell, S. P. *et al*. Light-gap disturbance, recruitment limitation, and tree diversity in a Neotropical forest. *Science* **283**, 554–557 (1999).

11. Mackey, R. L. & Currie, D. J. The diversity-disturbance relationship: is it generally strong and peaked? *Ecology* **82**, 3479–3492 (2001).

12. Hughes, A. R., Byrnes, J. E., Kimbro, D. L. & Stachowicz, J. J. Reciprocal relationships and potential feedbacks between biodiversity and disturbance. *Ecol. Lett.* **10**, 849–864 (2007).

13. Bongers, F., Poorter, L., Hawthorne, W. D. & Sheil, D. The intermediate disturbance hypothesis applies to tropical forests, but disturbance contributes little to tree diversity. *Ecol. Lett.* **12**, 798–805 (2009).

14. Fox, J. W. The intermediate disturbance hypothesis should be abandoned. *Trends Ecol. Evol.* **28**, 86–92 (2013a).

15. Fox, J. W. The intermediate disturbance hypothesis is broadly defined, substantive issues are key: a reply to Sheil and Burslem. *Trends Ecol. Evol.* **28**, 572–573 (2013b).

16. Sheil, D. & Burslem, D. F. Defining and defending Connell's intermediate disturbance hypothesis: a response to Fox. *Trends Ecol. Evol.* **28**, 571 (2013).

17. Huston, M. A. Disturbance, productivity, and species diversity: empiricism versus logic in ecological theory. *Ecology* **95**, 2382–2396 (2014).

18. Huston, M. A. A general hypothesis of species diversity. *Am. Nat.* **113**, 81–101 (1979).

19. Kershaw, H. M. & Mallik, A. U. Predicting plant diversity response to disturbance: applicability of the intermediate disturbance hypothesis and mass ratio hypothesis. *Crit. Rev. Plant. Sci.* **32**, 383–395 (2013).

20. Conn, J., Quinones, M. & Povoa, M. Phylogeography, vectors, and transmission in Latin America (ed. Manguin, S), Ch. 5, 145–149 (InTech Open Access Publisher, 2013).

21. Calzada, J. E. *et al*. Characterization of a recent malaria outbreak in the autonomous indigenous region of Guna Yala, Panama. *Malar. J.* **17**, 459 (2015).

22. Eastwood, G. *et al*. Enzootic arbovirus surveillance in forest habitat and phylogenetic characterization of novel isolates of Gamboa Virus in Panama. *Am. J. Trop. Med. Hyg.* **94**, 786–793 (2016).

23. Aitken, T. H., Downs, W. G., Anderson, C. R., Spence, L. & Casals, J. Mayaro virus isolated from a Trinidadian mosquito. *Mansonia venezuelensis. Science* **131**, 986 (1960).

24. Turell, M. J. *et al*. Vector competence of Peruvian mosquitoes (Diptera: Culicidae) for epizootic and enzootic strains of Venezuelan equine encephalomyelitis virus. *J. Med. Entomol.* **37**, 835–839 (2000).

25. Alto, B. W., Connelly, C. R., O'Meara, G. F., Hickman, D. & Karr, N. Reproductive biology and susceptibility of Florida *Culex coronator* to infection with West Nile

virus. *Vector Borne Zoonotic Dis.* **14**, 606–614 (2014).

26. Turell, M. J. Vector competence of three Venezuelan mosquitoes (Diptera: Culicidae) for an epizootic IC strain of Venezuelan equine encephalitis virus. *J. Med. Entomol.* **36**, 407–409 (1999).

27. Day, J. F. & Stark, L. M. Frequency of Saint Louis encephalitis virus in humans from Florida, USA: 1990–1999. *J. Med. Entomol.* **37**, 626–633 (2000).

28. Turell, M. J. *et al*. Susceptibility of Peruvian mosquitoes to eastern equine encephalitis virus. *J. Med. Entomol.* **45**, 720–725 (2008).

29. Burton, G. J. Attack on the vector of filariasis in British Guiana. *Public. Health. Rep.* **79**, 137–143 (1964).

30. Turell, M. J. *et al*. Potential for mosquitoes (Diptera: Culicidae) from Florida to transmit Rift Valley fever virus. *J. Med. Entomol.* **50**, 1111–1117 (2013).

31. Loaiza, J. R. & Miller, M. J. Seasonal pattern of avian *Plasmodium*-infected mosquitoes and implications for parasite transmission in central Panama. *Parasitol. Res.* **112**, 3743–3751 (2013).

32. Alencar, J. *et al*. Flight height preference for oviposition of mosquito (Diptera: Culicidae) vectors of sylvatic yellow fever virus near the hydroelectric reservoir of Simplício, Minas Gerais, Brazil. *J. Med. Entomol.* **50**, 794–795 (2013).

33. Schiemann, D. J., Pinzón, M. L. & Hankeln, T. Anthropophilic *Anopheles* species composition and malaria in Tierradentro, Córdoba, Colombia. *Mem. Inst. Oswaldo Cruz*. **109**, 384–387 (2014).

34. Ahumada, M. L. *et al*. Spatial distributions of *Anopheles* species in relation to malaria incidence at 70 localities in the highly endemic Northwest and South Pacific coast regions of Colombia. *Malar. J.* **15**, 407 (2016).

35. Pinault, L. L. & Hunter, F. F. New highland distribution records of multiple *Anopheles* species in the Ecuadorian Andes. *Malar. J.* **10**, 236 (2011).

36. Dusfour, I., Issaly, J., Carinci, R., Gaborit, P. & Girod, R. Incrimination of *Anopheles* (*Anopheles*) *intermedius* Peryassú, *An.* (*Nyssorhynchus*) *nuneztovari* Gabaldón, *An.* (*Nys.*) *oswaldoi* Peryassú as natural vectors of *Plasmodium falciparum* in French Guiana. *Mem. Inst. Oswaldo Cruz.* **107**, 429–432 (2012).

37. Rios-Velásquez, C. M. *et al*. Experimental *Plasmodium vivax* infection of key *Anopheles* species from the Brazilian Amazon. *Malar. J.* **12**, 460 (2013).

38. Manrique-Saide, P. *et al*. Incrimination of the mosquito, *Aedes taeniorhynchus*, as the primary vector of heartworm, *Dirofilaria immitis*, in coastal Yucatan, Mexico. *Med. Vet. Entomol.* **24**, 456–460 (2010).

39. Salas, R. A. *et al*. Ecological studies of enzootic Venezuelan equine encephalitis in north-central Venezuela, 1997–1998. *Am. J. Trop. Med. Hyg.* **64**, 84–92 (2001).

40. Marchi, M. J., Pereira, P. A., de Menezes, R. M. & Tubaki, R. M. New records of mosquitoes carrying *Dermatobia hominis* eggs in the state of São Paulo, southeastern Brazil. *J. Am. Mosq. Control Assoc.* **28**, 116–118 (2012).

41. Suaza-Vasco, J. *et al*. The Sabethines of Northern Andean Coffee-Growing Regions of Colombia. *J. Am. Mosq. Control. Assoc.* **31**, 125–134 (2015).

42. Alfonzo, D. *et al*. Ecological characterization of the aquatic habitats of mosquitoes (Diptera: Culicidae) in enzootic foci of Venezuelan equine encephalitis virus in western Venezuela. *J. Med. Entomol.* **42**, 278–284 (2005).

43. Laporta, G. Z. & Sallum, M. A. Coexistence mechanisms at multiple scales in mosquito assemblages. *BMC Ecol.* **14**, 30 (2014).

44. Juliano, S. A. Species interactions among larval mosquitoes: context dependence across habitat gradients. *Annu. Rev. Entomol.* **54**, 37–56 (2009).

45. Lounibos, L. P. Competitive replacement and reduction. *J. Am. Mosq. Contr. Assoc.* **23**, 276–282 (2007).

46. Lainhart, W. *et al*. Epidemic and non-epidemic hot spots of malaria transmission occur in indigenous comarcas of Panama. *PLoS Negl. Trop. Dis.* **10**, e0004718 (2016).

47. Loaiza, J. R., Bermingham, E., Scott, M. E., Rovira, J. R. & Conn, J. E. Species composition and distribution of adult Anopheles (Diptera: Culicidae) in Panama. *J. Med. Entomol.* **45**, 841–851 (2008).

48. Barros, F. S., Arruda, M. E., Gurgel, H. C. & Honório, N. A. Spatial clustering and longitudinal variation of *Anopheles darlingi* (Diptera: Culicidae) larvae in a river of the Amazon: the importance of the forest fringe and of obstructions to flow in frontier malaria. *Bull. Entomol. Res.* **101**, 643–658 (2011).

49. Barros, F. S. & Honório, N. A. Deforestation and Malaria on the Amazon Frontier: Larval Clustering of *Anopheles darlingi* (Diptera: Culicidae) Determines Focal Distribution of Malaria. *Am. J. Trop. Med. Hyg.* **93**, 939–953 (2015).

50. MacArthur, R. H. & Wilson, E. O. The theory of island biogeography 22-40 (Princeton University Press 1967).

51. Tokeshi, M. Species Coexistence: Ecological and Evolutionary Perspectives 146-182 (Wiley-Blackwell 1998).

52. Rejmánková, E., Grieco, J., Achee, N. & Roberts, D. R. *Anopheles* mosquitoes - new insights into malaria vectors, (ed. Manguin, S.), Ch. 13, 397–446, (InTech Open Access Publisher, 2013).

53. Nobre, C. A. *et al*. Land-use and climate change risks in the Amazon and the need of a novel sustainable development paradigm. *PNAS* **113**, 10759–10768 (2016).

54. Galindo, P., Trapido, H., Carpenter, S. J. & Blanton, F. S. The abundance cycles of arboreal mosquitoes during six years at a sylvan yellow fever locality in Panama. *An. Entomol. Soc. Am.* **49**, 543–547 (1956).

55. Galindo, P., Srihongse, S., De Rodaniche, E. & Grayson, M. A. An ecological survey for arboviruses in Almirante, Panama, 1959-1962. *Am. J. Trop. Med. Hyg.* **15**, 385–400

(1966).

56. Galindo, P. & Grayson, M. A. *Culex* (*Melanoconion*) *aikenii*: natural vector in Panama of endemic Venezuelan encephalitis. *Science* **172**, 594–5 (1971).

57. Gibson, L. *et al*. Primary forests are irreplaceable for sustaining tropical biodiversity. *Nature* **478**, 378–381 (2011).

58. Myers, S. S. & Patz, J. A. Emerging threats to human health from global environmental change. *Annu. Rev. Environ. Resour.* **34**, 223–252 (2009).

59. Laporta, G. Z., Prado, P. I. K. L., Kraenkel, R. A., Coutinho, R. M. & Sallum, M. A. M. Biodiversity can help prevent malaria outbreaks in tropical forests. *PLoS Negl. Trop. Dis.* **7**, e2139 (2013).

60. Randolph, S. & Dobson. Pangloss revisited: a critique of the dilution effect and the biodiversity-buffers-disease paradigm. *Parasitology* 1–17 (2012).

61. Cohuet, A., Harris, C., Robert, V. & Fontenille, D. Evolutionary forces on *Anopheles*: what makes a malaria vector? *Trends Parasitol.* **26**, 130–130 (2010).

62. Hubbell, S. P. The Unified Neutral Theory of Biodiversity and Biogeography (Princeton University Press, 2001).

63. Enserink, M. Chikungunya: No Longer a Third World Disease. *Science* **318**, 1860–1861 (2007).

64. Windsor, D. M. Climate and moisture variability in a tropical forest: long-term records from Barro Colorado Island. *Panama* (1990).

65. Foley, D. H., Rueda, L. M. & Wilkerson, R. C. Insight into global mosquito biogeography from country species records. *J. Med. Entomol.* **44**, 554–567 (2007).

66. WRBU – The Walter Reed Biosystematics Unit. Available at: http://www.wrbu.org/. (Accessed: 4th August 2014).

67. Lachniet, M. S., Patterson, W. P., Burns, S., Asmerom, Y., & Polyak, V. Caribbean and Pacific moisture sources on the Isthmus of Panama revealed from stalagmite and surface water gradients. *Geophys. Res. Lett.* **34** (2007).

68. Poveda, G., Waylen, P. R. & Pulwarty, R. S. Annual and inter-annual variability of the present climate in northern South America and southern Mesoamerica. *Palaeogeograp, Palaeoclimatol, Palaeoecol* **234**, 3–27 (2006).

69. Landsat 8 – U. S. Geological Survey. Available at: http://landsat.usgs.gov/landsat8.php. (Accessed: 10th February 2017).

70. VectorMap. Available at: http://www.mosquitomap.org/. (Accessed: 7th March 2014).

71. Pecor, J. E., Mallampalli, V. L., Harbach, R. E., & Peyton, E. L. Catalog and illustrated review of the subgenus *Melanoconion* of *Culex* (Diptera: Culicidae). *Contrib. Am. Entomol. Inst*. (1992).

72. Wilkerson, R. C., Strickman, D. & Litwak, I. B. T. R. Illustrated key to the female anopheline mosquitoes of Central America and Mexico. *J. Am. Mosq. Contr. Assoc.* **6**, 7–34 (1990).

73. Sallum, M. A. M. & Forattini, O. P. Revision of the Spissipes Section of *Culex* (*Melanoconion*) (Diptera: Culicidae). *J. Am. Mosq. Contr. Assoc.* **12**, 517–600 (1996).

74. Barcode of Life – Identifying Species with DNA Barcoding. Available at: http://www.barcodeoflife.org/. (Accessed: 18th May 2014).

75. Loaiza, J. R. *et al*. Novel genetic diversity within *Anopheles punctimacula* s.l.: Phylogenetic discrepancy between the Barcode cytochrome c oxidase I (COI) gene and the rDNA second internal transcribed spacer (ITS2). *Acta Trop.* **128**, 61–69 (2013).

76. Tamura, K. *et al*. MEGA5: Molecular evolutionary genetics analysis using maximum likelihood, evolutionary distance, and maximum parsimony methods. *Mol. Biol.*

Evol. **28**, 2731–2739 (2011).

77. GenBank - The genetic sequence database: collection of all publicly available DNA sequences. Available at: http://www.ncbi.nlm.nih.gov/genbank/. (Accessed: 10th July 2015).

78. Jansen, F. & Oksanen, J. How to model species responses along ecological gradient – Huisman-Olff-Fresco models revisited. *J. Veg. Sci.* **24**, 1108–1117 (2013).

79. Whittaker, R. H. Evolution of species diversity in land communities. *Evol. Biol.* **10**, 1–67 (1967).

80. Gotelli, N. J. & Colwell, T. K. Quantifying biodiversity: procedures and pitfalls in the measurement and comparison of species richness. *Ecol. Lett.* **4**, 379–391 (2001).

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Contributions

The study was designed by J.R.L., O.I.S., J.P. and M.J.P., and conducted by J.R.L., M.R., J.R.R., and J.P. Intensive mosquito sampling collection were undertaken by J.R.L., M.R., L.C.D., J.R.R., J.P., G.E., and D.F. Morphological mosquito species identification was carried out by J.R.L., J.R.R., and J.P. Molecular species confirmation was done by J.R.L. and L.C.D. Data analysis and graph preparation were done by G.Z.L. and J.R.L.; J.R.L. and G.Z.L. wrote the first draft and O.I.S., L.C.D., J.R.R., M.R., J.P., G.E., L.D.K., D.F., and M.J.P. contributed substantially to the final version of the manuscript.

Competing Interests

The authors declare that they have no competing interests.

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SPRINGER NATURE

CORNELL CHRONICLE

Provided

Dr. Christina McCullough, left, and Dr. Sara Childs-Sanford prepare a young bobcat for examination.

Veterinary college mends, releases injured bobcat

By Melissa Osgood | August 16, 2017

MEDIA CONTACT

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In April, Cornell's **Janet L. Swanson Wildlife Health Center** (http://vet.cornell.edu/hospital/services/wildlife/) (WHC) admitted a young male bobcat after he was hit by a car in Lansing, New York.

After receiving a call from a witness to the accident, WHC wildlife veterinarians worked with officers from the New York State Department of Environmental Conservation and a nuisance wildlife control operator to capture and transport the bobcat to WHC.

Radiograph of the bobcat's severely fractured humerus (a bone in the forelimb).

When he arrived, the bobcat was in critical condition and required several days of care to stabilize his condition and allow bleeding in his lungs to resolve. He was also diagnosed with a severely fractured humerus (a bone in the forelimb) and a hip that had been moved far out of the joint.

Dr. Ursula Krotscheck, chief of small animal surgery at the **Cornell University Hospital for Animals** (http://www.vet.cornell.edu/hospital/services/Companion/), evaluated the bobcat and radiographs of his forelimb fracture. The bone was fragmented into numerous pieces, and she determined that a metal plate was necessary to bring together the pieces and give the bobcat the best chance of healing.

Donating time, equipment and expertise to WHC, Krotscheck spent several hours performing the grueling procedure, challenged by anatomy that was different from her domestic patients and by a fracture that was extremely difficult to repair. After a few days of recuperation, the bobcat underwent another surgical procedure by Krotscheck, in which his severely dislocated hip was addressed. WHC veterinarians continued to provide the bobcat with care and aggressive pain control for the next several days, until the rehabilitation phase of his care could begin.

The bobcat was transferred to licensed wildlife rehabilitator **Cindy Page** (http://www.pagewildlifecenter.com/about-us/), who housed the bobcat in a small area at first to restrict his activity and allow the bones to heal. He was given privacy but remained secretive, wary of humans and aggressive when approached. After approximately 10 weeks of rest and healing, he was returned to WHC for a checkup.

The results of the radiographs were stunning: a beautifully healed fracture with perfect alignment. An exam showed good range of motion of the injured hip as well. He had grown, gained weight and was in excellent condition. As he recovered from anesthesia in a large dog crate, his release plans were solidified for the following day.

College of Veterinary Medicine

A bobcat hit by a car in Lansing, New York, received treatment at the Janet L. Swanson Wildlife Health Center to repair a severe front leg fracture and dislocated hip.

With assistance from Todd Bittner, director of natural areas for Cornell Botanic Gardens, a large area near his original home range was chosen. At noon on Friday, July 28, the door of his crate was opened, facing onto a beautiful sunny meadow, while all of those involved in the bobcat's care silently looked on.

Among the onlookers were many people involved with his recovery – a representation of the steps and stages native wildlife such as the bobcat must go through when ill or injured. Despite the open door, the bobcat hunkered down toward the back of the carrier, apprehensive and unsure. With some coaxing and gentle tipping of the carrier forward, he finally made a break for it – shooting out of the carrier across the meadow toward a dense forest.

Melissa Osgood is assistant director of media relations and leadership communication at the College of Veterinary Medicine.

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Cornell University
College of Veterinary Medicine

Traveling the World for Planetary Health

Friday, September 15, 2017 - 2:25pm

A former bile bear relaxing at Animals Asia's China Bear Rescue Centre in Chengdu.

Veterinary Students Find Meaning in Global Clinical Research

When Cornell veterinary student Perry Koehler, DVM ’20, was in China's Sichuan province last summer, he noticed something peculiar about the product packaging. “Wine, teas, toothpaste, even household cleaners,” he lists off, “all marked with a bear.”

The symbol is powerful advertising in East Asia. It indicates bear bile, a common prescription in traditional Chinese medicine used to treat everything from sore throats and hemorrhoids to hangovers. Demand for the folk remedy drove Asiatic black bears onto the endangered species list and into factory farms, where they are confined in cruel “crush cages” for continuous bile extraction.

At a bear refuge near Chengdu, Koehler tested acetaminophen as a treatment for the lameness and foot pain that rescued bile bears often suffer after their long confinements. He found that very low doses of the readily available pain reliever produced significant results, without further damage to the bears’ ravaged livers.

Perry Koehler working in the lab at the China Bear Rescue Centre.

Koehler is one of 14 students from Cornell's College of Veterinary Medicine who traveled to destinations around the world last summer for clinical research that advances planetary health.

"Public health is really the history and heart of veterinary medicine," says Alex Travis, the college's associate dean for international programs and public health.

Many Cornell students have worked internationally to save wildlife species threatened with extinction, improve food animal production to reduce environmental impacts and fight emerging diseases that can spread from animals to people, according to Travis. "These research experiences shape students' careers and are often literally life-changing," he says.

The college's Expanding Horizons program, now in its 30th year, sends student researchers to developing countries. Students who worked in industrialized nations in 2017 received funding support through the Global Cornell initiative. Jai Sweet, the college's director of student services and multicultural affairs, coordinates all of the international clinical experiences.

West Africa bird market; photo courtesy FAO

The summer of 2017 found Cornell students working to improve dairy cow health and milk quality in Latin America, identify wild species hosting West Nile virus in Malaysia, track animal welfare in Japan's cat cafés, and look for human disease risks in Viennese rats. In many cases, their research focused on practices—from agriculture to conservation—that bring animals and humans into close contact.

"Because veterinarians work at the interface of people, animals and the environment, our profession is uniquely positioned to benefit both animal health and human health," Travis explains. Important threats to global health, including epidemic diseases, are emerging in the contact zones, he says, and the needs of developing nations are often the greatest.

Leanne Jankelunas, DVM '20, experienced one of these contact zones in Ghana's live bird markets, where she tracked avian influenza in the chickens, turkeys, guinea fowl, ducks and pigeons for sale. She visited markets around the capital city of Accra to collect samples, talk with sellers and identify food safety and hygiene practices that increase bird handlers' risk of infection.

It didn't surprise Jankelunas to find pathogens and antibodies from past infections in the birds, but she was disturbed to discover that public health messages targeting market leaders have not trickled down to sellers. Most do not wash their hands often, wear gloves or masks, or change clothes after handling birds.

"As I would talk to these people, it would break my heart," she says. "They're on the front line, but most have no idea that people can get sick from this work."

From rapid turnover at the markets to suspicion of government workers, the communication challenges are complex, Jankelunas says. To prevent future bird flu outbreaks, the international community needs to act now with top-to-bottom education initiatives and funding for personal protection equipment.

Leanne Jankelunas in the lab.

For her own part, Jankelunas hopes to return to the developing world to work on pandemics such as Zika and Ebola. “Before this summer, I was pretty certain I wanted to work in international medicine,” she says. "Going on this Expanding Horizons program was just my way of deciding that this is exactly the kind of work I am meant to do.”

Story by Sheri Englund
This story was originally appeared on Global Cornell.

WATCH RECORDINGS

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"Closing Reflections and What's Next," **Gina McCarthy**, Former EPA Chief Administrator; Spring Fellow Institute of Politics, Harvard Kennedy School

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