RESEARCH HIGHLIGHTS

Smithsonian
Institution

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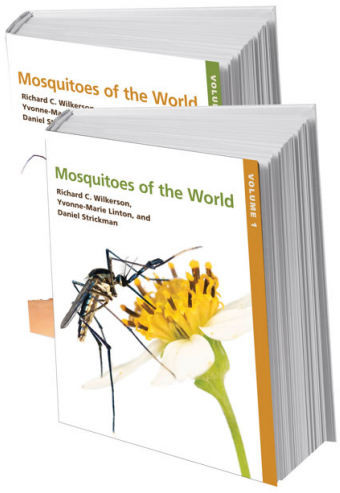
SMITHSONIAN RESEARCH CONTINUES THROUGH THE GLOBAL PANDEMIC

Given the global COVID-19 pandemic, the following stories highlight Smithsonian research that has continued despite closure of museums and labs and curtailed research travel, and work that is relevant to "One Health"—the concept that human health, livestock health, wildlife health, and environmental health are all closely inter-connected. These highlights also show the collaborative nature of the Institution's research, not only across Smithsonian units, but also with embedded staff from U.S. government agencies, in this case the Departments of Agriculture and Defense. While Smithsonian staff have largely been teleworking during the pandemic, staff working on agency missions, making identifications to protect agriculture and aviation, have continued to use the national collections onsite. Smithsonian research often involves combining the best of traditional specimen collections with cutting edge methods in cryopreservation and DNA analysis, as well as ecological modeling, in order to identify organisms, characterize their interactions, and predict how their associations may change over time, and how, in the end, that will impact "One Health." Despite being closed, the Smithsonian was also able to convene the cultural community in national outreach efforts to help educate the public on the pandemic.

THE DEFINITIVE RESOURCE ON THE BIOLOGY, EVOLUTION, AND DIVERSITY OF MOSQUITOES



Mosquitoes of the World, *Volumes 1 and 2. Richard C. Wilkerson, Yvonne-Marie Linton, and Daniel Strickman.*

Biting multiple times on two, three, or more different hosts, it is no surprise that some species of mosquitoes have co-evolved with pathogens. For humans and other animals, the result has been some of the most challenging diseases known. It has been said that Anopheles gambiae, as the primary transmitter of malaria parasites to humans, is the most dangerous animal in the world. Certainly, malaria has killed more people than all the wars that ever took place. Even now, despite drugs and mosquito control, malaria claims the lives of 405,000 people per year. The vast majority of mosquito species are not involved in pathogen transmission to humans, but those that are make a huge impact on global health.

In this two-volume set, three of the world's leading experts on mosquito disease, ecology, and systematics—all of whom spent most of their careers associated with Smithsonian—offer readers unique insights into the fascinating world of mosquitoes while illustrating their diagnostic morphological features in detail. Comprehensively addressing the natural diversity of mosquitoes, the book explains their life histories, bionomic traits, and the physiological and physical adaptations they evolved in response to ever-changing environmental conditions. These books form the new synthetic foundation for global understanding of mosquitoes.

This work represents 50 years of collaboration between the Smithsonian and the Department of Defense. The authors are Yvonne-Marie Linton, Research Director of The Walter Reed Biosystematics Unit ("WRBU") for the U.S. Army and curator for the Entomology Department of the **National Museum of Natural History** ("NMNH"), Richard Wilkerson, Smithsonian Research Associate at **NMNH** and the retired Research Director for WRBU, and the late Daniel Strickman who was a researcher and administrator associated with WRBU.

PROTECTING AMERICAN AGRICULTURE AND AVIATION SAFETY DURING THE PANDEMIC

Most Smithsonian research staff have been working at home since mid-March 2020 because of pandemic safety protocols, while building management and collections management staff have continued to secure the collections. Several parts of the **National Museum of Natural History** ("NMNH") collections, however, have remained active with staff serving essential U.S. government agency missions to protect agriculture and aviation safety.

The National Museum of Natural History's entomology collection has many Asian giant hornets. Recently, the collection grew with new specimens from an eradicated nest in Washington State. Credit: Matthew Buffington, USDA-ARS

"Urgent" interceptions of insects and mites detected at U.S. ports of entry arrive daily and must be identified immediately by U.S. Department of Agriculture ("USDA") staff at NMNH. USDA staff have used the National Insect Collection as a unique spatiotemporal database to assist with specimen identifications of 14,300 urgent lots containing 39,238 specimens to protect U.S. agriculture and natural resources from potential invasive pests. One high-profile urgent example that was submitted for identification using the National Insect Collection was the discovery of the Asian giant hornet (aka the "Murder Hornet") in Washington state. Subsequent specimens of the Asian hornet have been placed into both the pinned collection and cryorepository in Suitland, Maryland.

Another example of the essential use of the collections at NMNH involves the Birdstrike Identification Program. Because of long-standing Interagency Agreements with safety offices within the U.S. Air Force, U.S. Navy and Federal Aviation Administration, the Smithsonian's Feather Identification Lab maintained essential status during the pandemic. Over 9,000 bird strike identifications were completed, and relied on the vast bird collections at NMNH. Significant bird strike events during fiscal year 2020 included a Bald Eagle strike to a U.S. Navy aircraft causing over $5 million in damages; a National Transportation Safety Board crash investigation; and the identification of a Mallard Duck that caused Air Force 2 to return to the airport during a Presidential campaign event for former Vice President Mike Pence. The NMNH collections serve as the fundamental resource for species identification of bird strike evidence and helps airports manage habitat to be less attractive to birds improving aviation safety for all.

While digital data and images from the collections allow many uses to continue without physical access, some activities, such as confirmation of species-level identifications of animals and plants, often requires comparison of actual specimens. These examples also demonstrate some of the conclusions of the recent report "Economic Analyses of Federal Scientific Collections" published by the **Smithsonian Scholarly Press** on behalf of the U.S. Interagency Working Group on Scientific Collections (shared in the January 2021 Highlights). For example, the value of scientific collections grows over time as specimens and information are added, allowing our scientists to better understand the potential impact of a pest insect.

STUDYING LARGE HERBIVORES ACROSS LAIKIPIA RANGELANDS IN KENYA TO INFORM CONSERVATION

Grevy's Zebra, Credit: Ramiro Crego

A pair of recent papers in *Landscape Ecology* (DOI: https://doi.org/10.1007/s10980-021-01232-8) and *Biological Conservation* (DOI: https://doi.org/10.1016/j.biocon.2020.108436) analyze data accumulated over many years at the Mpala Research Centre in Kenya using new tools and make important observations on landscape connectivity and wildlife use of it, with actionable implications for design of roads, fences, and infrastructure in central Kenya.

Across the globe, the system of protected areas established to sustain biodiversity is failing or inadequate, compromising the conservation of natural ecosystems in the long-term. Incorporating private lands into conservation management plans is becoming increasingly important if wildlife are to persist into the future. Laikipia County in central Kenya contains a mosaic of communal and private lands that holds a diverse community of wild herbivores, including many endangered species. Land degradation, high livestock stocking rates and the increasing number of fences, however, are threatening the ecosystem and the species that depend on it for survival.

Using novel techniques to incorporate species detectability from two decades of aerial survey data, the research team—including lead author Ramiro Crego, Michael Brown, Peter Leimgruber, and Jared Stabach, all of the **Smithsonian Conservation Biology Institute**—estimated large herbivore community dynamics, inclusive of the response of wildlife to increasing levels of livestock across Laikipia rangelands in central Kenya. Results from these models are helping to identify key habitat linkages across the region, prioritizing areas for restoration to maintain historic levels of connectivity.

Results from the research indicate high spatial variation in species richness and species occupancy. Areas that are managed for wildlife conservation presented higher species richness than those that are not. Declines in wildlife richness were directly related to increases in livestock relative abundance. However, they found that certain pastoralist areas supported high levels of species richness, indicating that livestock and their wild counterparts can co-exist when livestock stocking densities are moderate to low. Balancing the needs of wildlife with those of humans is critical for the future sustainability of this ecosystem.

The research team was able to include in the study species such as Grevy's zebra, oryx, and gerenuk, which have been historically difficult to analyze at the regional scale because they are difficult to detect from aerial surveys. They found that several species with conservation concerns, such as reticulated giraffes, Grevy's zebras, oryx, and gerenuk, have only occupied less than 50% of Laikipia rangelands during the last twenty years. Increased protection for these species is critical given that all these species face high conservation challenges and Laikipia represents one of the last habitats left for them.

The team combined results from species richness and occupancy analysis with fine-scale fencing data collected across the region to assess landscape functional connectivity. They compiled the most comprehensive regional dataset on fences to date. Using modeling techniques, they identified areas across the landscape that will be critical to maintain or restore habitat connectivity and promote conservation for large herbivores. With the idea of making the results of the study more accessible to local conservancy managers and government officials, the team created an online Shiny app. This app allows users to dynamically interact with the maps and results, ultimately helping with the decision making and management process.

NEW MODEL FOR INFECTIOUS DISEASE COULD BETTER PREDICT FUTURE PANDEMICS

Increased human–animal interactions lead to the emergence and spread of zoonotic pathogens, which cause about 75% of infectious diseases affecting human health. In this photograph, wild zebras graze alongside a pastoralist and cows in Kenya. Credit: James Hassell.

In the midst of a devastating global pandemic of wildlife origin and with future spillovers imminent as humans continue to come into closer contact with wildlife, infectious-disease models that consider the full ecological and anthropological contexts of disease transmission are critical to the health of all life. Existing models are limited in their ability to predict disease emergence, since they rarely consider the dynamics of the hosts and ecosystems from which pandemics emerge.

Published in May in *Nature Ecology and Evolution*, Smithsonian scientists and partners provide a framework for a new approach to modeling infectious diseases. It adapts established methods developed to study the planet's natural systems, including climate change, ocean circulation, and forest growth, and applies them to parasites and pathogens that cause disease.

Increased human–animal interactions lead to the emergence and spread of zoonotic pathogens, which cause about 75% of infectious diseases affecting human health. Predicting where, how, and when people and animals are at risk from emerging pathogens—and the best ways to manage this—remains a significant challenge. Risks for spillover include, but are not limited to, habitat encroachment, illegal wildlife trade and bush meat consumption.

Despite advances in the understanding of how infectious diseases are transmitted, the models these efforts are based on are relatively limited in scope, focusing on specific pathogens and often overlooking how pathogens interact within their hosts. While scientists and global health organizations

are putting a lot of effort into studying the diversity of disease-causing organisms, existing models do not link this diversity to their roles within ecosystems.

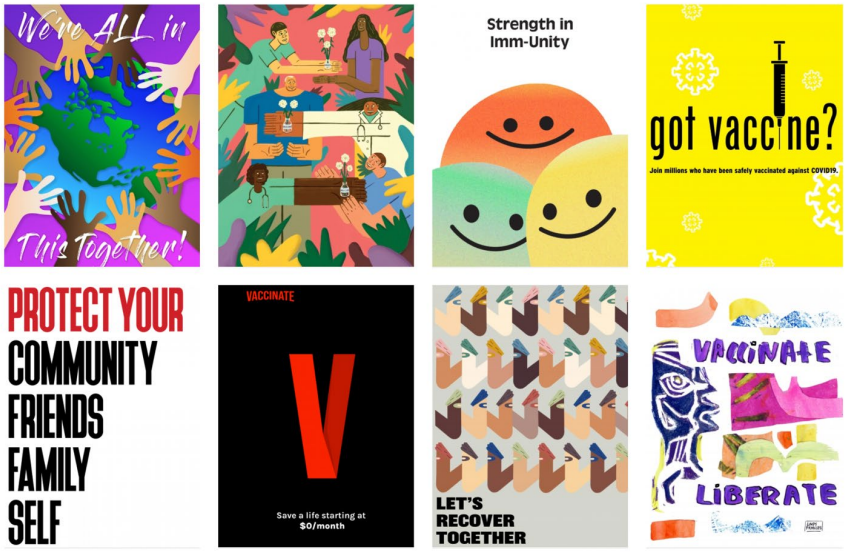
"Just as a mechanic must understand how a car's components interact and how it's been engineered in order to improve performance, the same applies to our ability to model infectious disease," said first author Dr. James Hassell, wildlife veterinarian, epidemiologist and Keller Family Skorton Scholar for the **Smithsonian Conservation Biology Institute's** ("SCBI") **Global Health Program**. "Applying systems-level thinking to forecast disease emergence requires a fundamental change in how we conceptualize infectious diseases. This presents significant challenges, but in this article, we explain why they're not insurmountable. When you weigh the cost of prevention versus remediation, the investment in our shared global health, particularly the connections between nature and human health, is vital."

Researchers say this new model will require expertise and collaboration across fields such as veterinary and human medicine, disease ecology, biodiversity conservation, biotechnology and anthropology. While the amount of data that would be required to create these models is daunting, long-term studies of intact ecosystems where parasite data has been collected are excellent places to initiate these studies. Efforts to refine them more broadly could then leverage large-scale ecological studies that span continents such as the Smithsonian's **ForestGEO** and **MarineGEO** programs.

The potential impacts of this new model go beyond reducing the human interface for disease spillover, to economics. "You could use this new approach not only to look at human diseases, but also to look at the best way to conduct aquaculture or raise healthy livestock," said Katrina M. Pagenkopp Lohan, a marine disease ecologist at the **Smithsonian Environmental Research Center** ("SERC")**.** "If you're reintroducing a species into the wild, what do you need that ecosystem to look like for you to be successful? We could actually model that. It's mind blowing."

In an era of big data and massive advances in technology, this kind of approach is achievable but requires enhanced data collection, sharing, and testing at far greater scales than currently occur.

VACCINES & US UNITES CULTURAL ORGANIZATIONS FOR COMMUNITY HEALTH



A sample of posters available for download on vaccinesandus.org

In April, the Smithsonian announced the launch of a new nationwide initiative, "**Vaccines & US: Cultural Organizations for Community Health**." This Smithsonian-led initiative brings together museums, libraries, and cultural institutions across the country to support the national effort to provide Americans with accessible, trustworthy information about vaccines. The initiative shares free resources that local cultural organizations can use to help their communities make informed decisions about COVID-19 vaccination.

Since the initiative launched, a new 11th collaborator joined the effort—the Brooklyn Public Library. The site continues to evolve with new information, a myriad of online events hosted by both the Smithsonian and collaborators, a set of a dozen vibrant posters available for download and distribution, and contributions from the community, including personal essays from former NASA administrator Major General Charlie Bolden and Astronaut Tom Jones.

Feedback from the community has been positive. One of more than 1,300 cultural professionals who tuned in for REopening Archives, Libraries, and Museums ("REALM")-sponsored webinar said, "Learning about **www.vaccinesandus.org** was worth the training alone!" And one followed up, "I have already used some of the discussion strategies in sharing information about the vaccines."

Co-Directors Amy Marino, **Office of the Under Secretary for Science and Research** and her mentor and Smithsonian alumna Dr. Zahava Doering, have been most encouraged by the enthusiasm from rural communities. For example, the Director of the Carter County Museum, located in a rural community in southeastern Montana, reached out after seeing the **Vaccines & US** announcement in the American Association for State and Local History ("AASLH") newsletter. For the past year, the museum has been working on a curriculum/exhibit project about the life of Dr. Maurice Hilleman, his ties to Montana, and the story of vaccine development and infectious disease. The exhibit will open Memorial Day weekend at the Carter County Museum and Dr. Doering will offer keynote remarks at the virtual kick-off event on May 28 . One copy will then travel to other rural communities in the state, enhancing public understanding of the role viruses play in human health, which will help build health literacy in rural areas.