RESEARCH HIGHLIGHTS

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ONE IN FOUR TREE DEATHS IN BLUE RIDGE MOUNTAINS LINKED TO INVASIVE SPECIES
THREE DECADES OF MONITORING REVEALS VIRGINIA FORESTS' RISKS, RESILIENCE

New research from the **Smithsonian Conservation Biology Institute ("SCB"I)** and **ForestGEO** finds that invasive species of forest insects and pathogens contributed to about a quarter of the tree deaths in Virginia's Blue Ridge Mountain forests in the past three decades. According to the authors, this is the first study to evaluate the long-term impact of the multiple invasive species affecting forests. The results, published in the journal *Ecosystems*, have implications for the protection of forest health and mitigation of climate change.

"As the world struggles with COVID-19, we are becoming increasingly aware that health is globally interconnected—that a disease agent accidentally transferred to a new host can have devastating consequences," said Kristina Anderson-Teixeira, forest ecologist at SCBI and the **Smithsonian Tropical Research Institute** and lead author of the study. "We expect more exotic tree disease agents to arrive in the future, and how we handle that threat will have important consequences for the health and diversity of our forests, along with their ability to help sequester carbon dioxide from the atmosphere and slow climate change."

Non-native insects and pathogens can cause significant harm when brought to a new environment by human activity. In the Blue Ridge Mountain region alone, invasive species have led to the classification of seven tree species as threatened or endangered.

Beyond individual types of trees, however, scientists have not previously studied how invasive species affect entire forests in the long term. For this research, Anderson-Teixeira and her co-authors studied decades of data from forest plots at Shenandoah National Park and the neighboring SCBI. At SCBI, this includes a plot from the Smithsonian's Forest Global Earth Observatory ("ForestGEO"), a worldwide network of forest monitoring sites.

The research plots are distributed across an 80-mile stretch of the Blue Ridge Mountains in Virginia. According to the authors, these plots are by no means unusual among forests of the eastern United States, which have all been subjected to multiple invasive species. Scientists have monitored the plots for years to measure the growth, death, abundance and diversity of tree species present. Combined, the records total more than 350,000 tree observations dating from 1987 to 2019.

Anderson-Teixeira and her team focused on the impact of eight invasive species, including insects like the gypsy moth and emerald ash borer, as well as fungi that cause disease in trees. They found that these eight species contributed to substantial increases in tree mortality over the past three decades. Their findings attribute about 25% of tree deaths to non-native insects and pathogens, with at least 22 tree species affected. The study also reveals the resilience of these forests, however. Despite significant losses to individual tree species, the total number of species present remained relatively constant, and there was no overall reduction in the number and size of the trees. Other tree species compensated for the losses, making the forests stable over the past several decades.

This long-term forest data demonstrates how invasive species have shaped entire ecosystems over time. Despite past resilience, invasive species continue to pose a growing threat to forests, and limiting their spread is important to maintaining the health and diversity of these forests.

THE BIOLOGY OF BIG

At 100 feet long and weighing more than 100 tons, blue whales are the largest creatures to have evolved on the planet. Other whales, like killer whales, are larger than most terrestrial animals but pale in comparison to the size of blue whales. What sets these two weight classes of whales apart? And what is stopping the biggest whales from growing even bigger?

"Blue whales and sperm whales are not just kind of big," said Nicholas Pyenson, curator of fossil marine mammals at the **National Museum of Natural History**. "They are among the biggest animals ever to have evolved. They rival and, in some cases, exceed the heaviest dinosaurs. That's pretty spectacular. But why aren't they bigger?" Pyenson said biologists have wondered for a century what limits animal size. Because the planet's largest living creatures spend most of their time beneath the ocean surface, where their behavior is difficult to monitor, ideas about what influences and limits their size have been mostly speculative. But now an international team of scientists, led by Pyenson and Stanford University biologist Jeremy Goldbogen, has collected data from hundreds of feeding whales, allowing them to determine how much energy species of different sizes invest to capture their prey and which of these species reap the greatest rewards for their efforts. Their findings, featured on the cover of *Science* in December, reveal that body size in all whales is limited by the availability of their prey, but only filter-feeding whales have evolved a feeding strategy that rewards and drives them to achieve the largest body sizes to have ever evolved on Earth.

To glean data for their study, the team of more than two dozen scientists sought and tagged whales, porpoises and dolphins of various sizes—from 5-foot-long harbor porpoises to gigantic blue whales. To track the animals' underwater activities, the team used multi-sensor tags that they temporarily affixed via suction cups, reaching from their boats with long poles to stick them on to the animals' backs. Once in place, accelerometers, pressure sensors, cameras and hydrophones in these high-tech tag devices reported on the animals' movements as they submerged to feed. Using sonar devices in the surrounding waters and past records of prey in whale stomachs, the scientists also estimated the density of prey in each tagged predator's vicinity. The team analyzed data from more than 10,000 feeding events in waters from Greenland to Antarctica. They used that data to calculate the energetic costs, benefits and total payoff of foraging for each whale. The relationship between body size and energetic payoff, they found, depended on what feeding strategy a whale had evolved to use—whether a whale was a filter feeder that gulps down schools of prey and strains them from ocean water in their mouth or, instead, a toothed hunter that catches prey individually.

Blue whales, humpbacks and other filter-feeding whales use baleen—rows of flexible hair-like plates in their mouths—to strain krill and other small prey from ocean water. They seek out dense patches of their prey and almost always, the data showed, consume more calories than they expend when they feed. For filter-feeding whales, large size is no impediment to foraging: blue whales, fin whales, and humpback whales, the largest whales in this study, achieved greater energy payoff during feeding events than any other whale in the study. Toothed whales, instead, use echolocation to forage and are limited to feeding on one prey target at a time. They must also dive deeper than other whales to find the largest and most abundant prey, like deep-sea squid and fish. Few other warm-blooded predators can access the parts of the ocean where large toothed whales feed. Below 1,000 feet, Pyenson said, "there's nothing else down there except all the squid you can eat." But squid must be chased, and that, the data showed, takes a lot of energy—especially for the biggest toothed whales. In some cases, the largest toothed whales did not eat enough food during a dive to make up for the energy they spent getting there. "They literally can't eat enough to achieve a higher energetic payoff before they have to return to the surface and breathe," Pyenson said.

Sperm whales, which can be up to 60 feet long, are not only larger than any other of today's toothed whales, but are also bigger than all of their fossil ancestors. That makes sense, Pyenson said, because based on the relative energy efficiencies that the team calculated for different-sized toothed whales, "being a sperm whale today is really pushing a serious biological limit." The team's calculations suggest that sperm whales would not be able to find enough of the largest squid prey to maintain their body size if they were any larger—there simply are not enough large squid in the ocean to sustain bigger sperm whales.

In contrast, large filter-feeding whales are not limited in their body size by the availability of their prey in the same way as toothed whales. Filter-feeding whales feed on small but very abundant krill prey that flourish at high population densities for short periods of time in specific parts of the world. As a result, Goldbogen, Pyenson and colleagues speculate that the seasonal availability of their abundant prey is what ultimately limits size in today's filter-feeding ocean giants like fin whales and blue whales.

These massive proportions and the giant appetites that go along with them are relatively new features in whales' evolutionary history. In 2017, Pyenson, Goldbogen and another colleagues found that the ancestors of today's whales maintained modest proportions until about five million years ago, when they evolved to take advantage of newly abundant but patchily distributed food sources. But 100 million years ago, other giants roamed the Earth—and Pyenson said their body size, too, was probably limited by the food supply. "We don't know how badly a herd of sauropod dinosaurs would chomp down on a forest in the Cretaceous period, but they probably did a number on it," he said.

Tropical forests can handle the heat, up to a point

Tropical forests face an uncertain future under climate change, but new research published May 22 in *Science* suggests they can continue to store large amounts of carbon in a warmer world, if countries limit greenhouse gas emissions.

The world's tropical forests store a quarter-century worth of fossil fuel emissions in their trees alone. There are fears that global heating can reduce this store if tree growth reduces or tree death increases, accelerating climate change.

The research team of nearly 200 international scholars included Stuart Davies, Director of the **ForestGEO** network, Jefferson Hall of the **Smithsonian Tropical Research Institute**, and the late Terry Erwin of the **National Museum of Natural History** who passed away in May 2020. The team measured over half a million trees in 813 forests across the tropics to assess how much carbon is stored by forests growing under different climatic conditions today.

The study revealed that tropical forests continue to store high levels of carbon under high temperatures, showing that in the long run these forests can handle heat up to an estimated threshold of 32 degrees Celsius in daytime temperature.

Yet this positive finding is only possible if forests have time to adapt, they remain intact, and if global heating is strictly limited to avoid pushing global temperatures into conditions beyond the critical threshold.

Lead author Dr Martin Sullivan, from the University of Leeds and Manchester Metropolitan University, said: "Our analysis reveals that up to a certain point of heating, tropical forests are surprisingly resistant to small temperature differences. If we limit climate change, they can continue to store a large amount of carbon in a warmer world.

"The 32-degree threshold highlights the critical importance of urgently cutting our emissions to avoid pushing too many forests beyond the safety zone.

"For example, if we limit global average temperatures to a 2°C increase above pre-industrial levels this pushes nearly three-quarters of tropical forests above the heat threshold we identified. Any further increases in temperature will lead to rapid losses of forest carbon.

"Each degree increase in temperature would release 51 billion tons of CO_2 from tropical forests to the atmosphere".

Forests release carbon dioxide into the atmosphere when the amount of carbon gained by tree growth is less than that lost through tree mortality and decay.

The study is the first to analyze long-term climate sensitivity based on direct observation of whole forests across the tropics. The research suggests that over the long-term temperature has the greatest effect on forest carbon stocks by reducing growth, with drought killing trees the second key factor. The researchers concluded that tropical forests have long-term capacity to adapt to some climate change, in part because of their high biodiversity, as tree species better able to tolerate new climatic conditions grow well and replace less well-adapted species, over the long-term. But maximizing this potential climate resilience depends on keeping forests intact.

SMITHSONIAN EXPERT IN INFECTIOUS ANIMAL DISEASES ANSWERS QUESTIONS ON THIS PANDEMIC – AND THE NEXT ONE

While many of us may only have become aware of the links between viruses, wildlife, and habitat destruction recently, Dr. Suzan Murray has spent much of her career studying the intersection of human, wildlife, and environmental health. A zoo veterinarian at the **Smithsonian Conservation Biology Institute ("SCBI")**, and both the program director of SCBI's **Global Health Program** and its chief wildlife veterinary medical officer, in 2016, Suzan spoke at the World Economic Forum's Annual Meeting of the New Champions, offering a vision of what would be needed to stop pandemics before they start.

In May 2020, the World Economic Forum ("WEF") repurposed Suzan's 2016 talk at their China meeting into a current interview and a new WEF article.

The Q&A style article indicates that with over 1.6 million viruses predicted to exist in nature, if we do not act now, the likelihood of another pandemic occurring in our lifetimes is substantial. Dr. Murray explained that scientists have learned a lot about how closely interlinked human and animal health are. There are many drivers of disease emergence and both the number of drivers and their rate of occurrence are increasing. Human activity is a common factor to many of these, including changes in land use like deforestation, or expanding cities bringing high human population densities closer to previously wild areas. These factors are forcing wild species into contact that would not otherwise take place with domesticated animals and humans, increasing the likelihood that new or unknown diseases could be passed on.

Dr. Murray said, "One of the biggest takeaways for me is that while we've talked about the global economy for decades, we haven't thought of health in that way. Unfortunately, this coronavirus has now demonstrated that health is a global issue and we are all connected – all species, all nations, all continents."

SMITHSONIAN SCIENTISTS DISCOVER BRIGHTEST SUPERNOVA EVER SEEN

In April, scientists at the **Center for Astrophysics | Harvard & Smithsonian** announced the discovery and study of the brightest, most energetic, and likely most massive supernova ever identified.

SN2016aps is believed to be an example of a "pulsational pair instability" supernova, and may have formed as the result of the merging of two massive stars prior to the explosion. The explosion energy of SN2016aps was ten times that of a normal-sized supernova.

"SN2016aps is spectacular in several ways," said Edo Berger, Harvard University professor and co-author on the paper. "Not only is it brighter than any other supernova we've ever seen, but it has several properties and features that make it rare in comparison to other explosions of stars in the universe."

The team—made up of researchers from CfA, University of Birmingham, Northwestern University, and Ohio University—first identified the supernova in 2016 using data from the Panoramic Survey Telescopes and Rapid Response System ("Pan-STARRS"). A four-year follow-up study tracked its slow evolution and significant energy release. Archival images retrieved during the study revealed a rising light curve dating back to December 2015, allowing the team to better understand the nature and explosion of the supernova.

In a typical supernova, radiation in visible light accounts for just one percent of the total explosion energy of 10^{51} erg. In SN2016aps, the explosion energy of 10^{52} erg is unprecedented, and the supernova radiated about 50 percent of this energy, making it outshine normal supernova explosions by 500 times.

"The intense energy output of this supernova pointed to an incredibly massive star progenitor," said Berger. "At birth, this star was at least 100 times the mass of our Sun."

Scientists don't believe the explosion got that big on its own. "Spectroscopic observations during the follow up study revealed a restless history for the progenitor star," said Matt Nicholl, of the University of Birmingham and lead author of the study. "We determined that in the final years before it exploded, the star shed a massive shell of gas as it violently pulsated. The collision of the explosion debris with this massive shell led to the incredible brightness of the supernova. It essentially added fuel to the fire."

SN2016aps also held another surprise for scientists: high levels of hydrogen gas. Massive stars typically lose the majority of their hydrogen to stellar winds long before they begin pulsating. "That SN2016aps held onto its hydrogen prompted us to theorize that two less massive stars had merged together, since lower mass stars hold onto their hydrogen for longer," said Berger. "The new star, borne of the merger, was heavy with hydrogen and also high enough in mass to trigger pair instability."

Future research regarding extremely luminous supernovae is bright, according to Berger. "The identification of SN2016aps has opened pathways to identifying similar events from the first generations of stars. With the upcoming LSST we can find such explosions from the first billion years in the history of the universe, and there will be plenty of examples then."

April also marks one year since scientists obtained the first image of a black hole, using Event Horizon Telescope observations of the center of the galaxy M87. The discovery, announced one year ago, has been considered as one of the most interesting science stories of 2019. The Event Horizon Telescope Collaboration had been awarded a number of prestigious awards and titles for its ground-breaking results.

Two Smithsonian Scholars Recognized for Prestigious Awards

Dr. Anna K. ("Kay") Behrensmeyer was elected to the National Academy of Sciences in recognition of distinguished and continuing achievement in original research.

Kay Behrensmeyer is Curator of Vertebrate Paleontology at the **National Museum of Natural History**. In 2018, Kay was named the recipient of two of the most prestigious honors in the field of paleontology in recognition of her monumental contributions to the field: the Simpson-Romer medal, the highest honor of the Society of Vertebrate Paleontology, and the Paleontological Society medal, that's society's premier award.

Much of Kay's career has involved paleontological and geological field research on the ecological context of human evolution in the later Cenozoic of East Africa. Currently, she is working on human origins-related projects in Kenya - the Olorgesailie Basin and East Turkana - as well as continuing her 40+-year study of modern taphonomy in Amboseli National Park.

Kay was elected to the National Academy of Arts and Sciences in 2011 and received the R. C. Moore Medal for excellence in Paleontology from the Society for Sedimentary Geology in 2016.

Dr. Jim Zimbelman was named the 2020 recipient of the G. K. Gilbert Award recognized by the Council of the Geological Society of America. The award is given annually in recognition of outstanding contributions to the interdisciplinary field of planetary geology.

Zimbelman served as the department chair of the **Center for Earth and Planetary Studies** at the **National Air and Space Museum** from October 2002 to February 2007, as part of a rotating chair position among the department scientists. He was elected a Fellow of the Geological Society of America in 1999, and he is a long-time member of the American Geophysical Union and the Geological Society of America. He has served on many committees for NASA. At NASM, Zimbelman is lead curator for development of the new *Exploring the Planets* gallery as part of the rebuilding effort underway at the museum, and he gives public lectures on a variety of topics in planetary science for the Smithsonian Institution's national and international lecture programs.

The Smithsonian has more than 20 active Fellows of the American Academy of Arts and Sciences and Members of the National Academies, four Members of the American Philosophical Society, and one Nobel Laureate.