



Smithsonian Institution

OUR SHARED FUTURE: RESEARCH HIGHLIGHTS JANUARY 2023

The following stories highlight Smithsonian research that has helped to shape and champion our strategic pan-Institutional initiatives, including **Life on a Sustainable Planet** and **Solving the Mysteries of the Universe**. These highlights also show the collaborative nature of the Institution's research, not only across Smithsonian units but in connection with leading universities and national and international research organizations aimed at mitigating the impacts of climate change and other types of human impacts on nature.

LIFE ON A SUSTAINABLE PLANET



The Smithsonian announced the launch of its “Life on a Sustainable Planet” initiative in November 2022 at COP27, the annual meeting of the Conference of Parties (“COP”) held in Sharm El-Sheik, Egypt. This is the Smithsonian’s latest major effort to collect new data about the changing planet, implement holistic and multi-scale approaches to environmental conservation, and educate the world about why and how sustainable solutions to climate change can benefit people and nature.

Through Life on a Sustainable Planet, the Smithsonian aims to promote evidence-based decision-making, working in concert with local communities, to address the climate crisis. Life on a Sustainable Planet will use the Institution’s 176-year history of scientific research and data gathering across a global network of research centers, its expansive museum collection and its diverse set of exhibits and educational programs to produce, curate and communicate strategies for adapting to and mitigating the impacts of climate change to the public. The Institution will pioneer new technologies to collect environmental data, develop new platforms to analyze and share these data and work with partners and communities to inform conservation action.

“Climate change threatens our livelihood. The Smithsonian is hopeful that, with the right approach, the world can adapt to and mitigate this crisis,” said Smithsonian Secretary Lonnie Bunch. “With Life on a Sustainable Planet, the Smithsonian hopes to set an example for the world on how to address this crisis effectively and equitably for all.”

“For more than 175 years, the Smithsonian has been building collections and undertaking research that shows how humans have pushed Earth’s delicate ecosystems towards a tipping point that threatens our long-term health, national security, and economic stability,” said Ellen Stofan, Under Secretary for Science and Research at the Smithsonian. “In response, we are working in the space where nature and human communities intersect, developing solutions that will make Earth more sustainable for all that live here.”

The launch of Life on a Sustainable Planet included a new website, science.si.edu, and a [short video](#).

SERC PARTNERS ON GALAPAGOS NON-NATIVE MARINE INVASIVE SPECIES ONLINE DATABASE



*Introduced Blue Crab *Cardisoma crassum* in mangroves on Santiago Island, Galapagos.
Photo: Inti Keith, CDF*

The Marine Invasions Research Laboratory of the **Smithsonian Environmental Research Center** (“SERC”) and the Charles Darwin Foundation (“CDF”) of the Galápagos, Ecuador announced in December the launch of the [Galápagos Non-native Estuarine and Marine Organisms database portal \(GalNEMO\)](#).

Though long treasured as a refuge for biodiversity—and its critical role in Darwin's theory of evolution—the Galápagos is not immune to invasion. In fact, more than 50 nonnative species have already found their way to the Galápagos Islands, [SERC and CDF reported in 2019](#)—more than 10 times the number scientists previously thought.

GalNEMO creates a baseline of introduced marine species in the Galápagos Marine Reserve (“GMR”) by synthesizing ongoing field research conducted by CDF and SERC scientists in the Galápagos with extensive literature review, and then documenting the results as part of an online, searchable database available to the public. This online platform will facilitate the exchange of information between researchers, decisionmakers, and other stakeholders involved in conservation, management, and public policy aimed to develop effective strategies for the conservation of the biodiversity of the Galápagos.

The GalNEMO portal is built upon the NEMESIS template, the [Marine Invasions Research Laboratory’s National Estuarine and Marine Exotic Species Information System](#), which documents non-native marine and estuarine invertebrates and algae introduced in the United States. Starting in 2015, SERC scientists traveled to the Galápagos to conduct standardized fouling surveys of local marine organisms alongside Inti Keith, principal investigator of CDF’s Marine Invasive Species Program, and her team. These surveys allow scientists to establish a baseline look of the marine fouling community’s diversity and structure, as well as monitor for non-native introductions that could arrive to this fragile ecosystem via the hulls of ships, ballast water, or other anthropogenic means. As the GMR is one of the Marine Protected Areas (MPAs) in the world, a UNESCO World Heritage Site, and rich in habitat and biodiversity with some species endemic only to these islands, monitoring nonnative species populations for changes and detecting newcomers is an important aspect of Galápagos conservation efforts.

Founded in 1959, the Charles Darwin Foundation for the Galápagos Islands is an international non-profit organization dedicated to scientific research for the conservation of the environment and biodiversity of the Galapagos archipelago. The Charles Darwin Foundation for the Galapagos Islands and the Smithsonian Environmental Research Center established a Memorandum of Understanding (“MOU”) in 2018 to conduct collaborative research to understand and sustain coastal marine ecosystems.

FOSSIL CSI: ANALYSIS OF MARINE REPTILE GRAVEYARD SUGGESTS BIRTHING GROUNDS SITE

Today's marine giants—such as blue and humpback whales—routinely make massive migrations across the ocean to breed and give birth in waters where predators are scarce, with many congregating year after year along the same stretches of coastline. Now, new research from a team of scientists suggests that nearly 200 million years before giant whales evolved, school bus-sized marine reptiles called ichthyosaurs may have been making similar migrations to breed and give birth together in relative safety.

The findings published in the journal [Current Biology](#), examine a rich fossil bed in the renowned Berlin-Ichthyosaur State Park (“BISP”) in Nevada’s Humboldt-Toiyabe National Forest, where many 50-foot-long ichthyosaurs (*Shonisaurus popularis*) lay petrified in stone. Led by Neil Kelley, Vanderbilt University scientist and former Smithsonian’s **National Museum of Natural History** Peter Buck postdoctoral fellow, and co-authored by the museum’s curator of fossil marine mammals Nicholas Pyenson, the study offers a plausible explanation as to how at least 37 of these marine reptiles came to meet their ends in the same locality—a question that has vexed paleontologists for more than half a century.

“We present evidence that these ichthyosaurs died here in large numbers because they were migrating to this area to give birth for many generations across hundreds of thousands of years,” Pyenson said. “That means this type of behavior we observe today in whales has been around for more than 200 million years.”

Over the years, some paleontologists have proposed that BISP’s ichthyosaurs—predators resembling oversized chunky dolphins that have been adopted as Nevada’s state fossil—died in a mass stranding event such as those that sometimes afflicts modern whales or that toxins from a nearby harmful algal bloom poisoned the creatures. The problem is that these hypotheses lack strong lines of scientific evidence to support them.

To try to solve this prehistoric mystery, the team combined newer paleontological techniques such as 3D scanning and geochemistry with traditional paleontological perseverance by poring over archival materials, photographs, maps, field notes, and drawer after drawer of museum collections for shreds of evidence that could be reanalyzed.

To do this, Kelley, Pyenson and the research team collaborated with Jon Blundell, a member of the **Smithsonian Digitization Program Office’s** [3D Program](#) team, and Holly Little, a long-time collaborator with Pyenson and the 3D Program’s team and currently the informatics manager in the museum’s Department of Paleobiology. While Pyenson and Kelley were physically measuring bones and studying the site using traditional paleontological techniques, Little and Blundell used digital cameras and a spherical laser scanner to take hundreds of photographs and millions of point measurements that were then stitched together using specialized software to create a 3D model of the fossil bed.

The research team found a key piece of the puzzle when they discovered tiny ichthyosaur remains among new fossils collected at BISP and hiding within older museum collections. Careful comparison of the bones and teeth using micro-CT X-ray scans at Vanderbilt University revealed that these small bones were in fact embryonic and newborn *Shonisaurus*.

“Once it became clear that there was nothing for them to eat here, and there were large adult *Shonisaurus* along with embryos and newborns but no juveniles, we started to seriously consider whether this might have been a birthing ground,” Kelley said.

Further analysis of the various strata in which the different clusters of ichthyosaur bones were found also revealed that the ages of the many fossil beds of BISP were separated by at least hundreds of thousands of years, if not millions.

“Finding these different spots with the same species spread across geologic time with the same demographic pattern tells us that this was a preferred habitat that these large oceangoing predators returned to for generations,” Pyenson said. “This is a clear ecological signal, we argue, that this was a place that *Shonisaurus* used to give birth, very similar to today’s whales. Now we have evidence that this sort of behavior is 230 million years old.”

The 3D scans of the site are now available for other researchers to study and for the public to explore via the open-source [Smithsonian’s Voyager platform](#), which is developed and maintained by Blundell’s team members at the Digitization Program Office. An interactive digital experience about the research team’s study, including a 3D model of ichthyosaur sites analyzed, is also available on the Digitization Program Office’s [website](#).

“Our work is public,” Blundell said. “We aren’t just scanning sites and objects and locking them up. We create these scans to open up the collection to other researchers and members of the public who can’t physically get to the Smithsonian.”

This research was conducted under research permits issued by the U.S. Forest Service and Nevada State Parks. It was supported by funding from the Smithsonian; University of Nevada, Reno; Vanderbilt University; and the University of Utah.

TEMPO: TRACKING AIR POLLUTION TO SUPPORT A SUSTAINABLE FUTURE FOR ALL

Weather satellites make it easy to track weather patterns across North America, but the same cannot be said about tracking air pollution. While our phones can tell us when it's going to stop raining to the minute, we do not have the same ability to measure and predict the movement of pollutants in the air as precisely. Air pollution comes from many sources, including wildfires, automobiles, and manufacturing plants. These emissions can spread across thousands of miles to threaten the health and well-being of entire ecosystems and communities. Fortunately, this coming spring, the **Center for Astrophysics | Harvard & Smithsonian** is launching the Tropospheric Emissions: Monitoring of Pollution ("TEMPO") instrument into geostationary orbit to allow scientists to track air pollution in near-real time to help us understand its causes and how it is impacting life on Earth so we can develop sustainable solutions for the future.



TEMPO will launch into geostationary orbit 22,236 miles above Earth's equator in 2023 as a payload on Intelstat 40e. © Maxar Technologies.

TEMPO will collect high-resolution information about air pollution across North America on an hour-by-hour basis, during daylight hours, enabling researchers to study where air pollution comes from, how it moves through our atmosphere, and the ways it affects our forests, oceans, and communities. Just like the weather, air pollution varies throughout the day and moves quickly, and by training TEMPO over North America, our scientists will be able to keep a close eye on how pollution fluctuates by the hour.

TEMPO will be the first space-based instrument that is capable of measuring North American air quality hourly in geographic segments as small as four square miles, or about the size of midtown Manhattan. The TEMPO instrument measures sunlight reflected from Earth's surface through the atmosphere. It is able to identify specific pollutants because each molecule creates a unique signature in the measured light. It will scan an area ranging from the Pacific to the Atlantic and from the Yucatán Peninsula in southern Mexico to the Alberta oil sands in northern Canada, encompassing most of the populated area of North America. It will enable us to analyze most types of pollutants, as well as other atmospheric threats, and their effects on our ecosystems and our lives.

STUDY DETAILS HOW ANIMALS ARE KEY TO RESTORING THE WORLD'S FORESTS



An aerial view of regenerating secondary tropical forests in the Barro Colorado Nature Monument, Panama. Credit: Cristian Ziegler, Max Planck Institute of Animal Behavior

The world faces a climate crisis paired with a record loss of biodiversity in every ecosystem. Increasingly, attention turns to forest restoration as a solution to these twin calamities. Forests soak up atmospheric carbon dioxide and provide habitats for organisms. Scientists interested in helping forests bounce back from deforestation typically focus on one thing—planting trees. But a new study at the **Smithsonian Tropical Research Institute** (“STRI”) underscores a powerful, yet largely overlooked, driver of forest recovery: the animals.

Led by an international team from the Max Planck Institute of Animal Behavior, STRI, the Yale School of the Environment and the New York Botanical Garden examined a series of regenerating forests in central Panama 20 to 100 years after they were abandoned. Their unique, long-term data set revealed that by carrying a wide variety of seeds into deforested areas, animals are key to the recovery of tree species’ richness and abundance to old-growth levels after only 40–70 years of regrowth. The [article](#), published in *Philosophical Transactions of the Royal Society B*, is part of an issue focused on forest landscape restoration as part of the UN Decade on Ecosystem Restoration.

“Animals are our greatest allies in reforestation,” said Daisy Dent, tropical ecologist from the Max Planck Institute of Animal Behavior, research associate at STRI and the study’s senior author. “Our study prompts a rethink of reforestation efforts to be about more than just establishing plant communities.”

The report also notes that situating regenerating forests near patches of old growth and reducing hunting encourage animals to colonize and establish.

“We show that considering the wider ecosystem, as well as features of the landscape, improves restoration efforts,” said Sergio Estrada-Villegas, a biologist now at Universidad del Rosario in Bogotá, Colombia, and the study’s first author.

Animals that eat fruit and drop their seeds elsewhere are key to forest expansion. In the tropics, over 80% of tree species can be dispersed by animals. Despite this, forest restoration efforts continue to focus on increasing tree cover rather than reestablishing the animal-plant interactions that underpin ecosystem function.

“Figuring out how animals contribute to reforestation is prohibitively hard because you need detailed information about which animals eat which plants,” Estrada-Villegas said.

Data collected from the forest at Barro Colorado Island in the Panama Canal offers a unique solution to this problem. In one of the best-studied tropical forests in the world, generations of scientists have documented plant-animal interactions to understand which groups of animals disperse which tree species.

In the current study, the team led by Estrada-Villegas and Dent examined this unique long-term dataset to determine the proportion of plants dispersed by four groups of animals—flightless mammals, large birds, small birds and bats—and how this proportion changed over a century of natural restoration. Their results offer the most detailed data of animal seed dispersal recovery across the longest timeframe of natural restoration.

“Most studies examine the first 30 years of succession, but our data spanning 100 years gives us a rare glimpse into what happens in the late phase of restoration,” Dent said.

The study found that young regenerating forests were made up mostly of trees dispersed by small birds. But as the forest aged, trees dispersed by larger birds increased. Surprisingly, however, across all forest ages—from 20 years old to old growth—most plants were dispersed by terrestrial mammals.

“This result is quite unusual for post-agricultural regenerating forests,” Dent said. “It is likely that the presence of large tracts of preserved forests near our secondary stands, coupled with low hunting, has allowed the mammal populations to thrive and to bring an influx of seeds from neighboring patches.”

“We hope this information helps practitioners to structure their restoration practices by enabling animals that disperse seeds to help the restoration process and speed up forest recovery,” Estrada-Villegas said.