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University of Arizona lab uses innovative data approaches to study biodiversity and climate change

From species extinctions to shifting climate patterns, the Data Diversity Lab combines ecology, spatial sciences and collaborative research to tackle some of the planet's most pressing environmental challenges.

Emma McDonough, News Editor

The University of Arizona's Data Diversity Lab gives researchers a new way to picture the future of life on Earth. By blending ecology, evolution and advanced data science, the lab creates tools aimed to streamline massive biological datasets — allowing scientists to more accurately predict biodiversity loss, climate change and long-term ecological impacts, along with guiding conservation efforts.

Founded in 2023 and led by ecologist and evolutionary biologist Cristian Román-Palacios, the lab investigates a range of questions about life on Earth. Such as how urbanization, shifting ecosystems and culturally learned behaviors affect species and their environments.

"Data science forms the backbone of our research, whether it's analyzing biological data, predicting patterns behind species extinctions or extracting meaningful data from letters written by students demanding social justice in academia," the lab's mission reads.

Natalie Benton

The Data Diversity Lab uses machine learning and mass data sets to answer some of the environment's most pressing questions. The Lab, founded at the University of Arizona in Tucson, Ariz., is led by Dr. Cristian Román-Palacios.

Much of the lab's work involves developing new algorithms and computational tools that can be applied to real-world problems.

"For the lab, I wanted to assemble a group of students and researchers who would collaborate on diverse topics," Román-Palacios said. "Rather than restricting themselves to specific areas, they would bring curiosity to provide input and feedback, ask questions and critically examine work outside their particular disciplines, drawing on their fundamental and transversal knowledge."

Datasets developed by the lab have supported research on topics such as freshwater fish diversity, plant evolution, climate-driven extinctions and changes to access in natural spaces worldwide. Taken together, this work offers a clearer picture of how species — and the ecosystems they rely on — are responding to unprecedented environmental shifts.

Román-Palacios explained that his goal for starting the lab extended beyond his formal training in biology. “The lab emerged from my ever-growing interest in how biology permeates not only our basic understanding of nature, but also how we see human societies and understand social conflict, inequalities and other phenomena,” Román-Palacios said.

The Data Diversity Lab post-doctoral researchers, PhD students and undergraduate students take a group picture. (photo courtesy of Cristian Román-Palacios)

The lab comes to life through the lab’s postdoctoral researchers, who each contribute their own specialties of research to the broader mission of understanding and having access to data on biodiversity.

Among the researchers pushing this mission forward is Ian Estacio, whose work bridges ecology, public health and urban planning. Estacio studies socio-ecological systems — the complex networks of people, landscapes and biological communities that shape modern life.

According to Estacio, one of the factors impacting biodiversity the most is land use change, including urbanization.

“Modeling and analyzing socio-ecological systems enable researchers to understand the effects of human-environment interactions on biodiversity,” Estacio said.

Estacio studies how people and the environment influence each other, using maps, satellite imagery and computer simulations to uncover those relationships. He explained that he gathers information through spatial science techniques, such as remote sensing, Geographic Information System and agent-based modeling, to acquire datasets on factors like air temperature, vegetation, population or land use.

From there, he uses models to simulate interactions between humans, wildlife and landscapes. According to Estacio, these models allow him to test how new policies or urban planning decisions might affect biodiversity, heat exposure and environmental equity.

The biggest challenge with socio-ecological modeling is accurately capturing the spatial processes that weave together social and environmental datasets, according to Estacio. “Modeling will always be an abstraction of reality — hence, there will always be limitations in modeling research,” Estacio said.

He explained that validation methods ensure that simulations match observable patterns, and thus can create reliable outcomes.

One of Estacio's research focuses is on Urban Heat Islands — areas within urban areas that become significantly hotter than surrounding areas due to buildings, roads and other surfaces that trap and radiate heat. This can create higher energy use, poorer air quality and increased health risks.

According to Estacio, his main goal within the Data Diversity Lab is to contribute to more sustainable planning of cities. "I hope that in the future, desert cities like Tucson can use the findings of my research to promote environmental justice and build sustainable cities," Estacio said.

From identifying areas at greatest risk of extreme heat to evaluating the cooling effects of new design strategies, he explained that his simulations offer tools for city planners, public health officials and local governments to plan for future climate change.

"We hope our research can pinpoint solvable issues and preventable pitfalls regarding ecosystem conservation," Román-Palacios said. "Through our findings, we aim to inform impactful decisions that foster conservation efforts and manage biodiversity on our planet."

Another major aspect of the lab's work focuses on understanding biodiversity on a global scale, often through tools designed to make complex ecological questions accessible to researchers everywhere.

Kristen Martinet, a postdoctoral researcher specializing in biodiversity modeling, develops and refines computational tools that help scientists measure how species diversity changes across different landscapes.

One of her central projects is the R package *ssarp* — the Species-/Speciation-Area Relationship Projector — which models patterns such as species distributions, extinction risk and environmental change. According to Martinet her interest in tool-building began during graduate school, when she found herself limited by poor software or databases.

"As a graduate student, I often felt frustrated that there were very few tools that would help me answer the biological questions on which I wanted to focus," Martinet said. "If tools did exist, they were often poorly documented and hadn't been maintained in years."

That gap pushed her to create the tools she needed. While studying island-dwelling lizards, Martinet developed a code pipeline to understand how non-native species affected species-area relationships — a foundational ecological principle describing how the number of species changes with the amount of land area.

"I wanted to ensure that the code pipeline I developed to conduct this research was well-documented and openly available for other researchers with similar questions to use for their own work," Martinet said. "This pipeline became my first R package, *ssarp*."

Today, *ssarp* helps researchers quantify and visualize biodiversity trends by standardizing how they use occurrence records — the millions of species observations stored in online databases like the Global Biodiversity Information Facility. These records make it possible to determine how many species live on a given island or landmass, which is the information needed to infer species-area relationships and speciation-area relationships.

"The *ssarp* R package makes quantifying and visualizing patterns of biodiversity on a global scale more accessible," Martinet said. "Trends in biodiversity are often disrupted by anthropogenic effects, such as habitat loss and fragmentation. Island systems are uniquely threatened due to their isolation, so monitoring island biodiversity is critical for conservation."

Looking ahead, according to Martinet, she hopes *ssarp* and future tools will help researchers compare biodiversity patterns at a global scale — something historically difficult due to inconsistent datasets and computational barriers.

"My hope is that the easily-accessible nature of the tools I develop will allow more researchers to ask questions about biodiversity in their study systems," Martinet said. "Making global comparisons more accessible will hopefully lead us to a clearer picture of the world's biodiversity."

Building on the lab's focus with biodiversity, Kiran Basava studies another layer of life on Earth — cultural diversity in animals and humans. Basava explained that she looks at behaviors animals learn from each other, such as how they find food, avoid predators, communicate, migrate and build habitats.

According to Basava, understanding these behaviors can help scientists understand how species respond to changes in the environment.

“The consideration of cultural diversity or socially learned behaviors has important implications for how species respond to climate change and other human-caused disturbances to the environment,” Basava said.

By combining this information with existing biodiversity data, Basava explained that scientists can see patterns that show how species adapt or struggle when their ecosystems are altered. “By bringing together information on animal behaviors, we can better understand how species survive and thrive,” Basava said. “This can help guide conservation efforts and protect biodiversity for the future.”

The Data Diversity Lab also ensures that diversity, equity and inclusion remain central to the way scientists conduct research and collect data. The lab shapes data inclusion not as an extension to research, but as a core part to its identity. “Our commitment to diversity and inclusion isn’t a separate initiative but a part of our lab’s DNA,” the lab’s mission reads.

“Our research seeks to advance understanding of biodiversity patterns and processes while educating the public about these critical issues,” Román-Palacios said.

For Román-Palacios and his team, the future of biodiversity research depends not only on stronger models and better data, but on broadening the amount of scientists who can use those tools.

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