

AN ACOUSTIC JOURNEY TO A TROPICAL ISLAND

Island-Wide Acoustic Monitoring in Puerto Rico



HUMAN ACTIVITIES AND SPECIES DISTRIBUTIONS

Understanding the current biodiversity crisis

The world faces a major biodiversity crisis. It is estimated that over the last 500 years, hundreds of animal species have gone extinct. Furthermore, many remaining species have experienced dramatic population declines due to the impacts of human activities, such as hunting, vehicle collisions, habitat loss, the introduction of exotic species, and global warming. To prevent this decline from continuing, it is essential to increase our knowledge and understanding of the natural history, ecology, and distribution of species of great conservation need and the habitats in which they occur.

Knowing the distribution of species is a baseline crucial information for conservation actions. When data on species presence are evaluated along with the environmental characteristics, such as elevation, precipitation, and age of forest, researchers can understand how the distribution of one species is related with environmental gradients that might be restricting its occurrence to a handful of locations. The more that is known about an organism, the more information we have available to use in protecting it and ensuring that in the future, more people can have the pleasure of seeing them in the wild.



Photo: Rainforest Connection researchers in the field in Puerto Rico island.



Photo: An AudioMoth autonomous recorder installed in the island of Puerto Rico.

CAPTURING THE SOUND OF NATURE

How listening to nature can protect biodiversity?

With technological development, new tools have emerged to help researchers collect large-scale and long-term data on the occurrence of species around the planet. One of those new technologies is passive acoustic monitoring (PAM), which uses stand-alone recorders installed in the field to gather data on all of the acoustically active species in an area.

There are numerous advantages of using PAM, such as the possibility of standardizing the simultaneous monitoring of different locations over a large sampling area, and collecting a massive volume of data that would be all but impossible for researchers to gather in the field on their own.

In addition, currently available analytical tools allow for creating models for semi-automatic and automatic identification of species that are present in the recordings gathered.

These tools enable researchers to use hundreds of thousands of recordings to answer their ecological questions, something that was previously untenable due to the number of hours required to manually analyze that colossal volume of collected recordings.

"The tools available with passive acoustic monitoring allow for the collection of a large volume of data to be standardized."

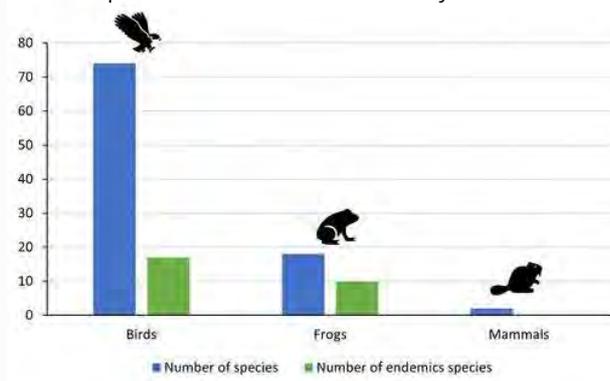
BIODIVERSITY IN PUERTO RICO

Puerto Rico is an archipelago among the Great Antilles that includes the eponymous main island and several smaller islands, such as Mona, Desecheo, Culebra, and Vieques. These islands host an incredible diversity of ecosystems and breathtaking landscapes. The Puerto Rico archipelago and all the Caribbean islands are also one of the world's main endemic biodiversity centers due to the region's geography and climate. That means that several species in Puerto Rico can't be found anywhere else in the world.

Nevertheless, Puerto Rico's biodiversity is under constant threat from both natural (i.e., hurricanes) and human (i.e., urbanization, climate change) disturbances. Unfortunately, we still don't have good information about the status of many species in Puerto Rico, nor how their population fluctuates and responds according to natural and human disturbances. What is needed is the development of population baselines for several bird and frog species so that we can detect unusual population trends and be able to manage species and ecosystems to avoid extinctions.

To improve knowledge about the distribution of bird, amphibian, and mammal species that occur in Puerto Rico, researchers from **Rainforest Connection**, in partnership with the **US Fish and Wildlife Service, Departamento de Recursos Naturales y Ambientales de Puerto Rico**, and the **Para la Naturaleza foundation** recently conducted an island-wide survey using PAM. The survey focused on the lowlands and coastal areas on the main island of Puerto Rico, a selection of elevational gradients in the mountainous regions, and the major offshore islands of Culebra, Desecheo, Mona and Vieques. Standalone recorders and the analytical tools of the **RFCx-Arbimon platform** were essential in allowing the collection of data from 841 sites across the archipelago during the three month peak of bird breeding season.

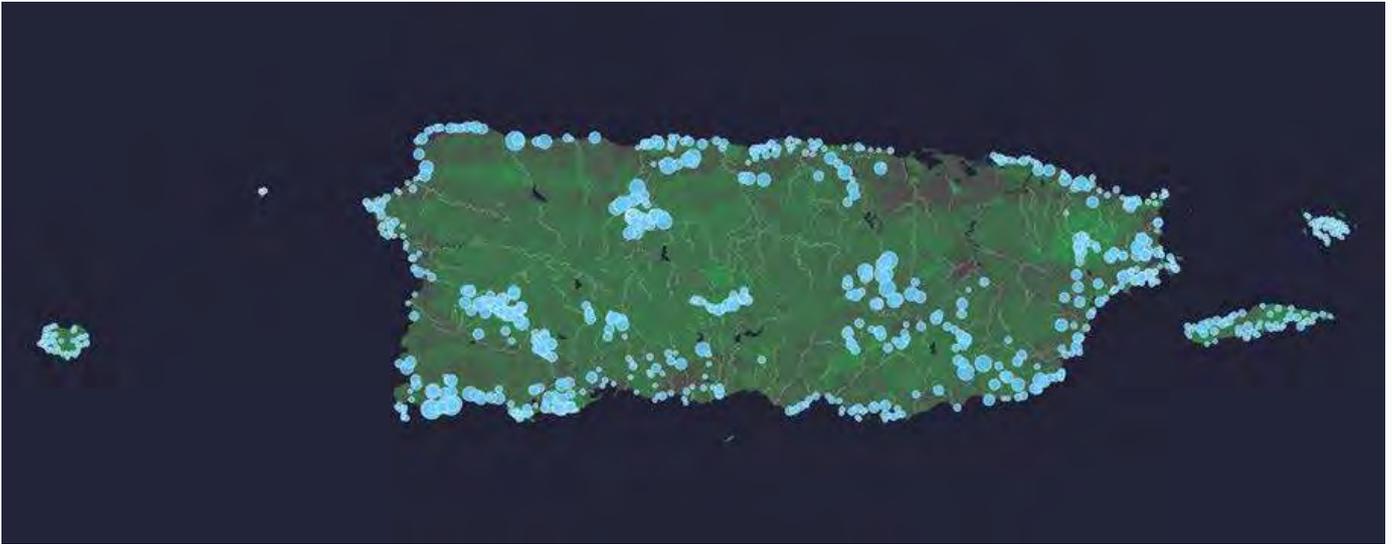
Vertebrate species richness found in our study in Puerto Rico.



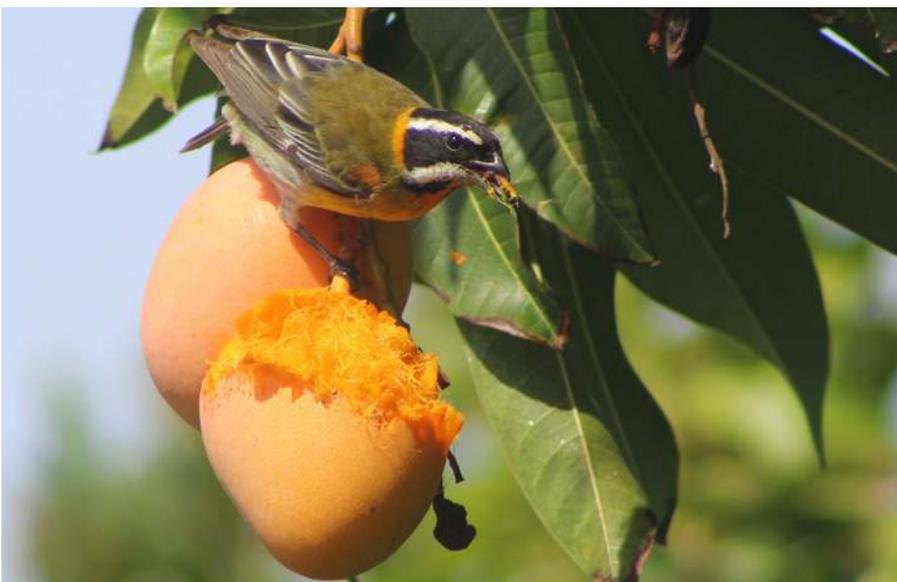
FIELDWORK

Rainforest Connection researchers installed standalone recorders between March 1 and July 5, 2021, at 690 field locations. To increase spatial coverage, data from 151 recorders across several projects developed in Puerto Rico were also used. Each recorder installed was considered a different location. The volume of recordings obtained was impressive! Nearly 2 million 1-min recordings with valuable biological information about multiple species.

The animal species in the recordings were later identified by scientists using the Arbimon platform by the Rainforest Connection team. This platform makes it possible for researchers to quickly identify species and create models to find a target species over a large number of recordings. It would be impossible for someone to obtain the same result manually.



Map of the island of Puerto Rico showing the location of the 841 sampling sites. The size of the blue circle's increases in proportion to the number of species detected at each point.



Endemic species recorded during the field activities in Puerto Rico island: Puerto Rican tody (*Todus mexicanus*) (photo above left), Mona Coqui (*Eleutherodactylus monensis*), this is an endemic and endangered species that only occurs on the island of Mona (photo above right), Puerto Rican Spindalis (*Spindalis portoricensis*) (photo below left) and Yellow-shouldered Blackbird (*Agelaius xanthomus*) (photo below right)

EXTRACTING BIOLOGICAL INFORMATION FROM THE AUDIO FILES

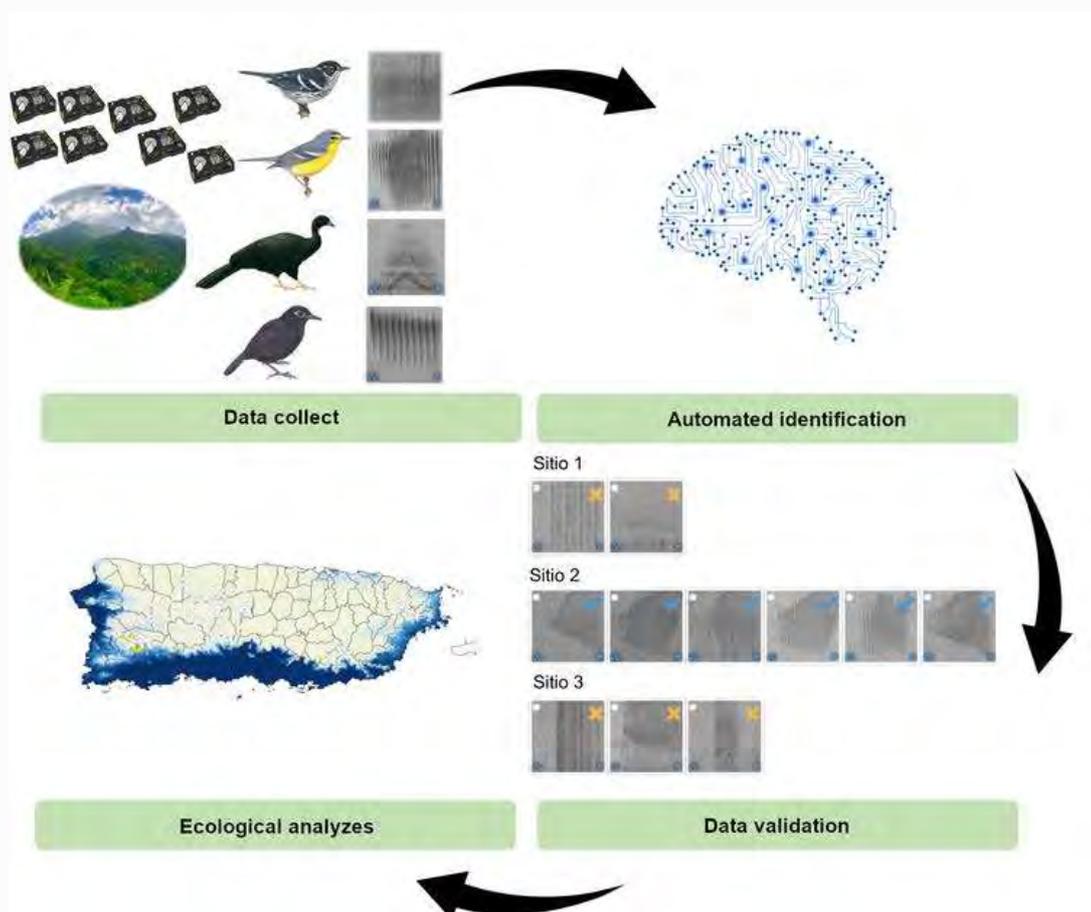
After uploading all recordings into Arbimon, the first step was to select, listen and annotate a subset of recordings from each location to identify a preliminary species list. The next step was to create species identification models to find the species' presence across all recordings. A good example of the species song or call (i.e., template) was chosen and used to create species identification models using a Pattern Matching procedure.

The Pattern Matching method finds patterns in the recordings similar to the template selected for each species. The user can define model sensitivity by choosing an appropriate threshold (i.e., model threshold). For example, with a lower threshold, Pattern Matching can find all the varieties on the target sound but may also erroneously select the presence of other sounds in the recordings (i.e., increases the rate of false positives). Thanks to our visualization plots, it is relatively easy to spot and eliminate false positives.

To ensure that the Pattern Matching results were reliable, Rainforest Connection scientists verified the outputs of all models, marking all matches that the algorithm correctly identified the presence of the species, a process known as model validation.

After all these steps, the researchers obtained valuable information from all the locations where each species was present or absent. The validated data were used in conjunction with six environmental variables: elevation, rainfall, the proportion of protected area, percentage of canopy cover, and the proportion of forest area in different stages of regeneration.

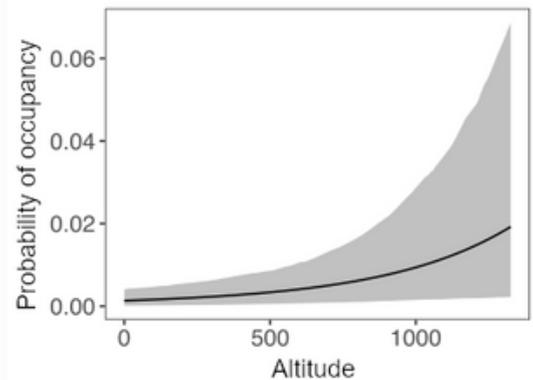
The joint analysis of this information allowed the researchers to build distribution maps and estimate the probability of occupancy, detectability, and the vocal activity pattern for each species.



General workflow used by the Rainforest Connection science team. With this approach, it is possible to answer numerous ecological questions.

For example, our results indicated that the Elfin-woods Warbler, a small endemic and threatened bird of Puerto Rico, is more likely to be found in areas with high values of forest cover, altitude, humidity, and proportion of protected areas. The species has a vocal activity peak in the early morning. These results, for example, reinforce the importance of safeguarding high-altitude areas with dense canopy cover and can help wildlife managers define new protected regions in mountainous environments to conserve this species. The presence of the Mountain Coqui, a tiny endangered frog species found only in Puerto Rico, was positively associated with high altitudes and rainfall but negatively related to secondary forests, indicating that secondary forests can not guarantee species preservation.

With the continuity of this study, it will be possible to compare how species are responding to changes caused by humans and natural disturbances, such as global warming or hurricanes. Join us in our effort to conserve Puerto Rico's Biodiversity!

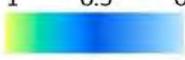
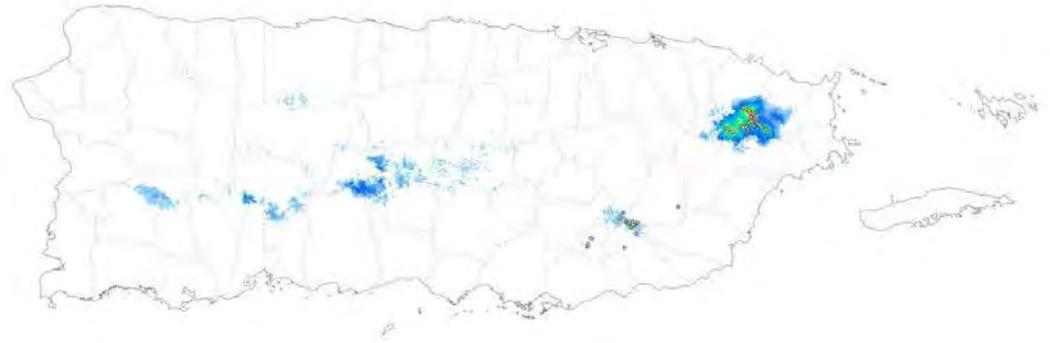


The probability of occupancy of Elfin-woods Warbler (*Setophaga angelae*) increases with altitude.

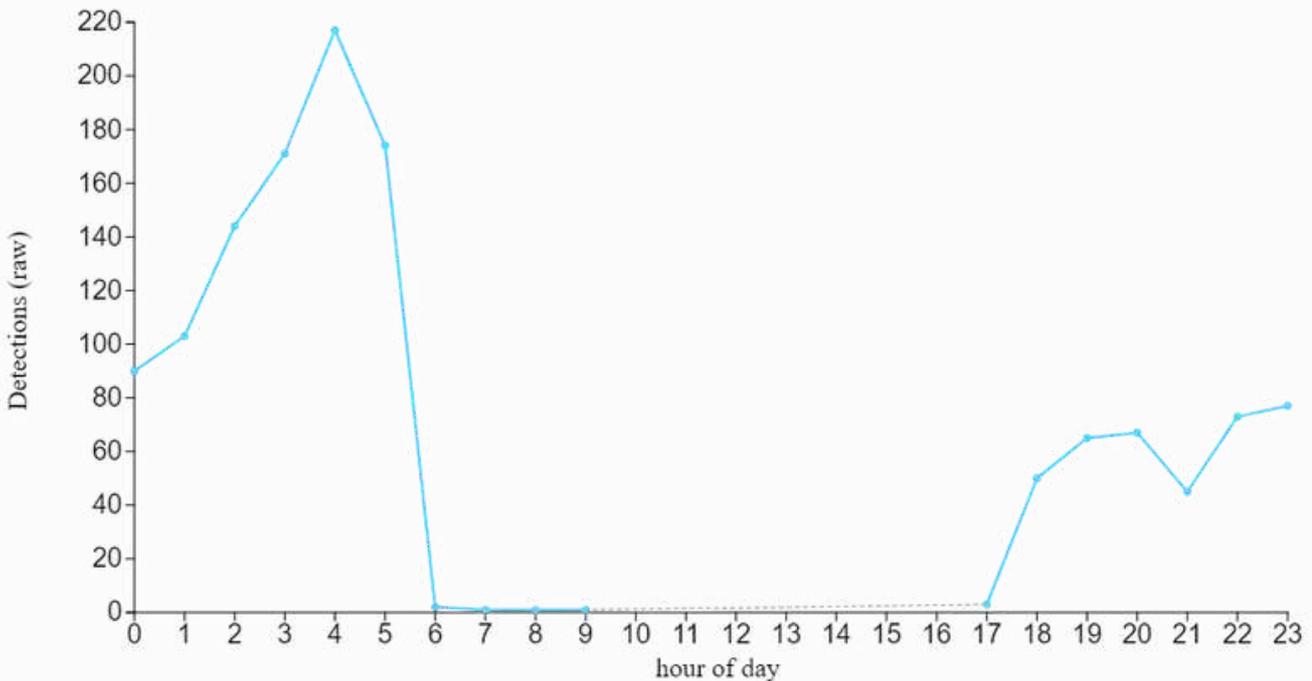
The results obtained with this project offer probably the most outstanding effort to understand the distribution patterns of several endemic and threatened species across the entire archipelago and could serve as a basis for further studies on the ecology and behavior of these species. In addition, the main results are freely available to everyone on the Biodiversity Insight platform (<https://bio.rfcx.org/puerto-rico-island-wide>), where it is easy to learn more about Puerto Rico's Biodiversity by exploring the results and data using maps, plots, figures, and sounds.

The Pattern Matching analysis: This tool available on the Arbimon platform, makes it possible to quickly obtain information on the presence and absence of a species in a large set of recordings. In this approach, an example of the sound of a target species is used, and the algorithm searches a set of recordings for patterns similar to the one defined by the user. The results can be validated later to ensure the quality of the data used in the ecological analyses.

● Species Presence
 Probability of Occupancy
 1 0.5 0

Occupancy probability map of the endemic and endangered Mountain Coqui (*Eleutherodactylus portoricensis*). On this map, colors closer to yellow and green indicate a higher probability of occupancy. The map is generated based on the results of the occupancy analysis, which showed that this species is associated with locations of higher altitude and precipitation and that it depends on primary forests.



The vocal activity of Mountain Coqui (*Eleutherodactylus portoricensis*) throughout the day. The species has a much higher peak of vocal activity just before dawn. This information can be helpful for researchers who plan to find this species in active searches in the field. Figures like this are available on the Biodiversity Insight platform for all detected species.