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# Harnessing the Power of Sound and AI to Track Global Biodiversity Framework (GBF) Targets

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# Executive Summary

Biodiverse ecosystems are critical to the overall health of our planet, providing numerous essential ecosystem services that underpin human well-being and the global economy. The landmark Global Biodiversity Framework lays out a series of powerful targets to combat the current biodiversity loss crisis. However, to track progress towards and ultimately achieve these targets at a global and continuous scale, we need to leverage the power of advanced technologies. Biodiversity monitoring is vital for tracking species trends over time and space, informing conservation efforts, and assessing how human activities affect ecosystems. However, incomplete biodiversity knowledge highlights the need for affordable, scalable technologies, such as ecoacoustics and artificial intelligence (AI), to fully realize the GBF targets. **Incorporating AI into passive acoustic monitoring (PAM) has the potential to revolutionize our understanding of ecosystems, species interactions, and the impacts of environmental changes.** By utilizing PAM and AI, researchers can gather data on the presence, distribution, and behavior of a wide range of species, from birds and mammals to insects and frogs. This information can then be used to inform conservation and management decisions, including identifying key biodiversity areas, establishing protected areas, evaluating wildlife management initiatives, and developing conservation strategies tailored to different species.

In this white paper, **we describe the power of PAM and AI (or ecoacoustics) to monitor biodiversity, inform conservation action, and track progress towards GBF targets.** We begin with a general overview of acoustic monitoring, including its benefits for threat detection and biodiversity monitoring, as well as the technology and infrastructure used. We then outline several case studies from our collaborative work around the world, to showcase the wide range of ecoacoustic applications. We align each of these real-world examples with specific GBF targets and their candidate indicators. Finally, we present key takeaways and areas for future advances in the use of ecoacoustics and AI for biodiversity monitoring. By leveraging this technology, we can make meaningful progress towards the protection and preservation of our natural world.

# Introduction

Biodiversity is the foundation of our planet's health and functioning, playing a crucial role in mitigating climate change, maintaining water and nutrient cycles, and provisioning our food supply. The loss of biodiversity can lead to the collapse of entire ecosystems, which can have cascading effects on other species and ecosystem services that people rely on. However, we are currently facing a severe biodiversity crisis that demands urgent and decisive action. There has been a 70% decline in wildlife populations since 1970 and an estimated 1 million species face extinction due to human activities; deforestation, land conversion, poaching, pollution, and climate change are the primary drivers of this biodiversity crisis.

In light of this critical situation, a significant stride has been taken with the recent adoption of the Kunming-Montreal Global Biodiversity Framework (GBF) at the latest United Nations Convention on Biological Diversity (COP15). This landmark statute lays out an ambitious set of 23 global biodiversity conservation targets to be achieved by 2030. Most of the attention has been on the targets themselves, but an important appendix deserving of equal consideration is the GBF monitoring framework. The first and most critical step to combating the biodiversity crisis is to generate accurate, systematic, reliable, and up-to-date information about biodiversity patterns to inform and track conservation actions.

# Introduction

The GBF monitoring framework outlines a series of headline, component and complimentary indicators used to track progress towards and achievement of the GBF targets. The monitoring framework specifically calls for the development of scalable technologies, expansive capacity building, and information sharing. These innovations are all the more important given that our current biodiversity datasets are insufficient, with significant taxonomic and geographic gaps. This makes it challenging for countries to gauge their progress toward GBF targets and limits our understanding of wildlife trends. Biodiversity monitoring involves the standardized and ongoing collection of data on the living organisms in a given area.

It provides essential data that can measure and track changes in species distribution, abundance, and diversity over time. Biodiversity monitoring is a crucial tool for understanding the effects of conservation actions and land-use change. This monitoring is also a fundamental and core step to achieving the 23 GBF targets. However, traditional monitoring methods (such as in-person observations) are time-consuming, labor-intensive, and costly. We need more accessible, cost-efficient methods to fill our biodiversity knowledge gaps. To overcome these challenges, it is imperative to utilize innovative monitoring methods and technologies that can provide near-real-time biodiversity data at a global scale.

Red-skirted tree frog
(*Dendropsophus rhodopeplus*)
Photo credit: Tomaz Nascimento de Melo

# Acoustic Monitoring

**Camera-trap**
Using motion-triggered trail cams to detect species or threats via images or video

**eDNA**
Extracting DNA from soil or water samples to detect species

**Remote sensing**
using distant sensors such as satellites or aircraft for Earth observation, GIS applications, geospatial analyses, etc.

**Artificial Intelligence**
Simulating human problem-solving and learning capabilities through computers/machines

**Passive Acoustic Monitoring**
Utilizing autonomous audio recorders to detect species or threats via sound

**Soundscape**
All the sounds emanating from a specific location and time period, including biophony (animal sounds), geophony (e.g., rain), and anthrophony (human sounds)

To better understand the impact of global changes on ecosystems and wildlife, cost-effective and scalable monitoring technologies are crucial. Conservation technologies such as **camera-traps, environmental DNA,** acoustic monitoring, and **remote sensing** are radically transforming biodiversity monitoring. Acoustics, in particular, is an exceptionally effective tool, particularly when coupled with the power of **artificial intelligence** (AI). **Passive acoustic monitoring** (PAM) involves the use of autonomous (i.e., they run on their own) recorders to capture and store all the sounds from an area. By combining this acoustic data with ecological information, we are able to generate ecoacoustic insights.

The power of ecoacoustics lies in its ability to capture all sounds of an ecosystem (the **soundscape**), providing a holistic and comprehensive wealth of information about the presence, distribution, and behavior of species. Acoustic monitoring is a reliable, scalable, and comprehensive way of quantitatively informing GBF indicators. By providing valuable information on the presence and distribution of different animal species, PAM can help track progress towards a variety of GBF targets. The combination of ecoacoustics and AI can expedite the monitoring of biodiversity patterns at global scales, contributing to reliable biodiversity metrics and indicators.

**Left:** Black-and-white ruffed lemur (*Varecia variegata*)

**Right:** Great reed warbler (*Acrocephalus arundinaceus*)
Photo credit: Tomaz Nascimento de Melo

# Acoustic Monitoring

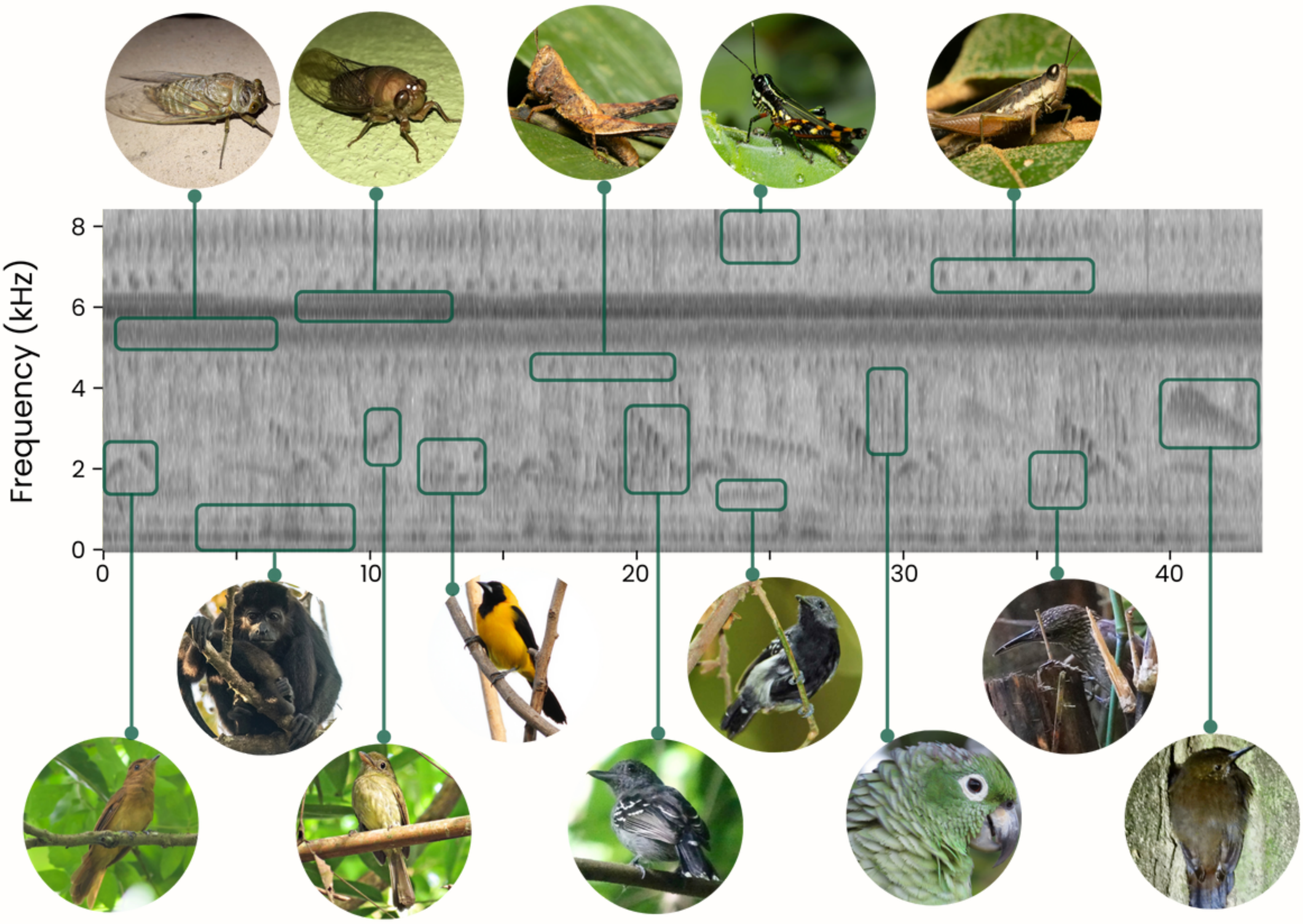
**Acoustic Indices**
Mathematical calculations that measure a soundscape based on the distribution of acoustic energy over time and frequency

**Species Richness**
The number of taxa at a site over a given time period (how many species)

Acoustic monitoring is an attractive option for surveying biodiversity because it is non-invasive (i.e., does not disrupt animals' natural behaviors) and minimizes on-the-ground effort, decreasing the time, labor, and cost required. Acoustic monitoring can be used to record sounds continuously for long periods of time and through traditionally difficult sampling times (e.g., at night, during bad weather). Recorders can simultaneously monitor multiple species and have a large, 360-degree detection radius. Acoustic monitoring allows for both species-level and community-level monitoring, providing a holistic understanding of biodiversity within a region.

At a macro level, soundscapes can be used to generate **acoustic indices** that have been shown to correlate with **species richness** and habitat type. Recordings can be archived and re-analyzed for different purposes, functioning as a veritable museum of soundscape artifacts and facilitating transparency and collaboration. This aligns with GBF Targets 20 and 21, which state the need for more robust and accessible capacity-building, technology transfer, and information-sharing tools and initiatives. Sharing acoustic data, models, knowledge, and insights can allow simultaneous reporting on various different taxonomic groups (demonstrated in Figure 1 below).

Figure 1. Spectrogram of the dawn chorus in Barro Colorado Island, Panama.



# Acoustic Monitoring and AI

Acoustic sensors are becoming increasingly affordable, compact, and accessible, shifting the bottleneck from data collection to data analysis. However, by harnessing the power of AI and cloud computing, we are overcoming this bottleneck as well. Recent advances in AI models now allow researchers to analyze acoustic recordings efficiently and accurately, providing ecological insights that would be implausible to obtain manually. AI models can be 'trained' to detect and identify species-specific sounds to determine species presence and distribution, as well as community-level metrics such as species richness and **species composition.**

Incorporating **machine learning** (ML) and **cloud computing** into acoustic monitoring for wildlife conservation brings numerous benefits, but it also presents challenges that need to be overcome. Luckily, the pace of innovation for both software and hardware has been rapid and new solutions are being developed at an unprecedented scale.

We focus in on three key challenge areas for acoustic monitoring and AI: data storage, cloud computing, and model deployment.

## Data Storage

As it becomes easier and cheaper to collect data, we face significant data storage challenges. Acoustic data can accumulate rapidly, resulting in high data storage costs, especially when dealing with long-term monitoring projects. **Edge ML**, where data is processed locally (in real-time) on the recording devices, can help mitigate this challenge. However, deploying and maintaining edge ML models can be complex, requiring careful consideration of power constraints, resource limitations, and quality control. Research is still needed to develop better compression techniques, both to run large models on the edge and to transfer large datasets. An increasing amount of research is being done on such new compression techniques, which are a promising avenue for decreasing storage costs.

**Species Composition**
The set of taxa present at a site over a given time period (i.e., which species)

**Machine Learning**
A subfield of AI in which models are "trained" to learn patterns from annotated data to automate detection or prediction tasks

**Cloud Computing**
Utilizing remote servers over the internet to store, access and analyze large datasets

**Edge ML**
ML algorithms run in real-time directly at data-collection point/sensor

# Acoustic Monitoring and AI

### Cloud Computing

While cloud computing and super-computers have increased the speed and efficiency of running AI models, doing so still requires large amounts of compute power and specialized server infrastructure. Training and running these models requires powerful hardware which can be expensive and logistically difficult to access. An increase in both efficiency and number of servers, along with new compression methods, provide a promising path to making cloud computing accessible to conservation practitioners.

### Model Deployment

Designing models that accurately identify and classify species' vocalizations while adapting to changing environmental conditions can be complex and time-consuming. AI models are typically very "data-hungry," and require extensive, diverse training datasets to learn relevant features for accurate classification. This can be challenging, especially for rare or cryptic species.

Sharing acoustic data from different locations and ecosystems allows models to learn more subtle distinctions in sound patterns and increase accuracy. When models are trained on data from various sites and conditions, they become more robust and better at generalizing to new datasets. This improved accuracy in turn contributes to more reliable conservation insights.

### Data Sharing

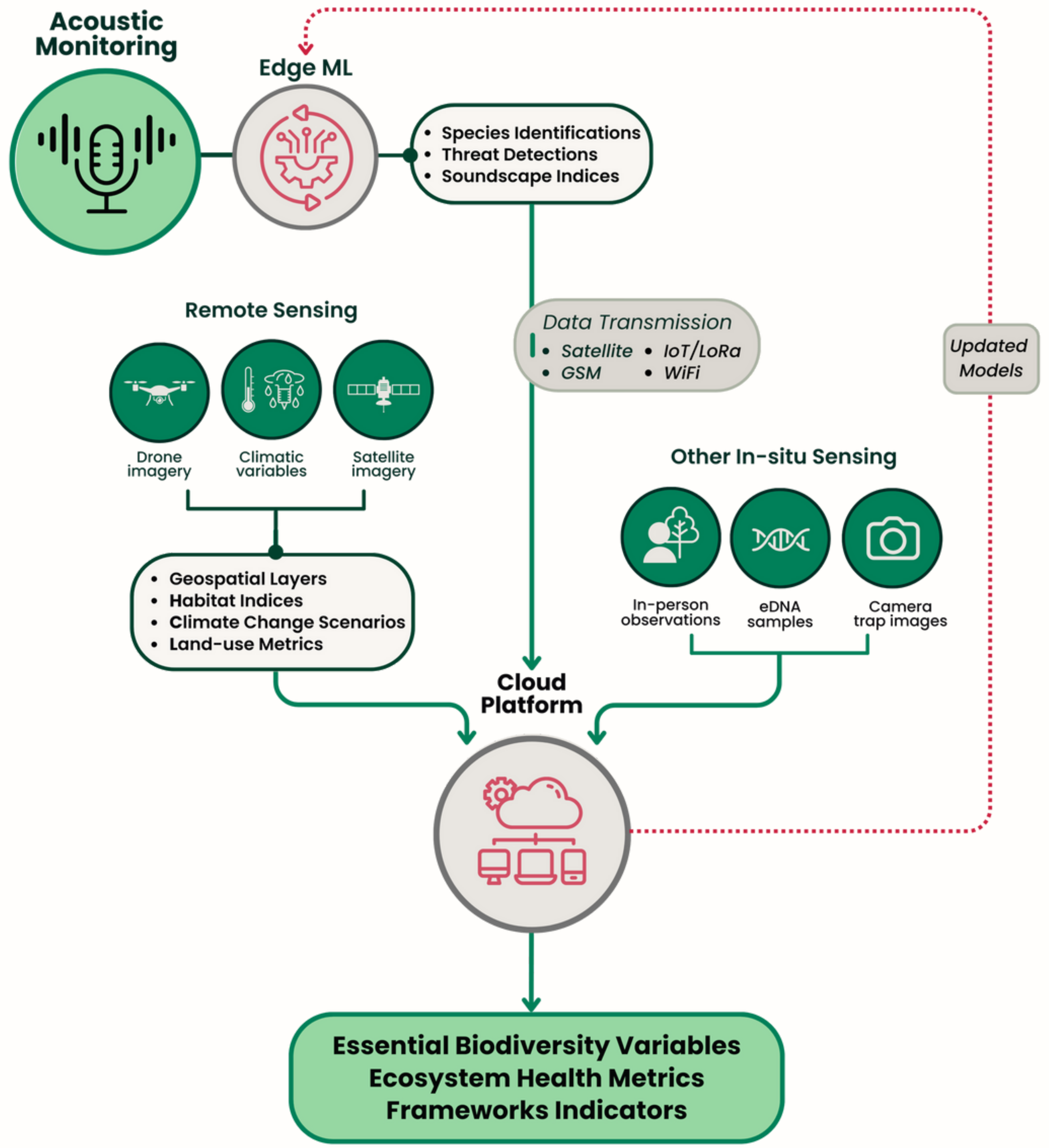
Acoustic monitoring generates massive amounts of audio data from different ecosystems and species. Sharing this data across research institutions, conservation organizations, and citizen science initiatives is important to create diverse training datasets. Beyond the logistical benefits of data sharing, it also fosters collaboration and transparency among researchers, conservationists, and technologists. This interdisciplinary collaboration is necessary to accelerate the advancement of ML techniques that are tailored to the needs and considerations of the conservation world.

# Acoustic Monitoring and AI

However, it is important to note that this must be balanced against data security protocols, particularly with sensitive data such as endangered species detections and human voices. Care must be taken to ensure that local governments, indigenous communities, and individual data owners retain equitable data sovereignty.

By overcoming the challenges in these three areas, we can begin to envisage a fully-integrated, multi-sensor infrastructure capable of generating continuous, near-real-time biodiversity data (Figure 2). This idealistic system would represent a radical step forward in how we process biodiversity data, make management decisions, and formulate conservation actions.

Figure 2: Idealistic ecoacoustic- and AI-enabled, end-to-end, biodiversity monitoring system with multi-sensor integration



# Case Studies

One of the greatest benefits of acoustic monitoring is the breadth of use cases it can be applied to, all of which can feed into various GBF targets (Figure 3). At Rainforest Connection (RFCx), we are harnessing the power of sound and AI to monitor biodiversity and detect threats to ecosystems at scale (Box 1). RFCx is now working in 40 countries to implement end-to-end ecoacoustic workflows.

Our approach is deeply collaborative; we work with various stakeholders including other nonprofits, government agencies, local communities, universities and corporate partners. In the following section, we highlight some of our case studies from around the world to showcase the potential of integrating PAM and AI to survey biodiversity and inform GBF indicators.

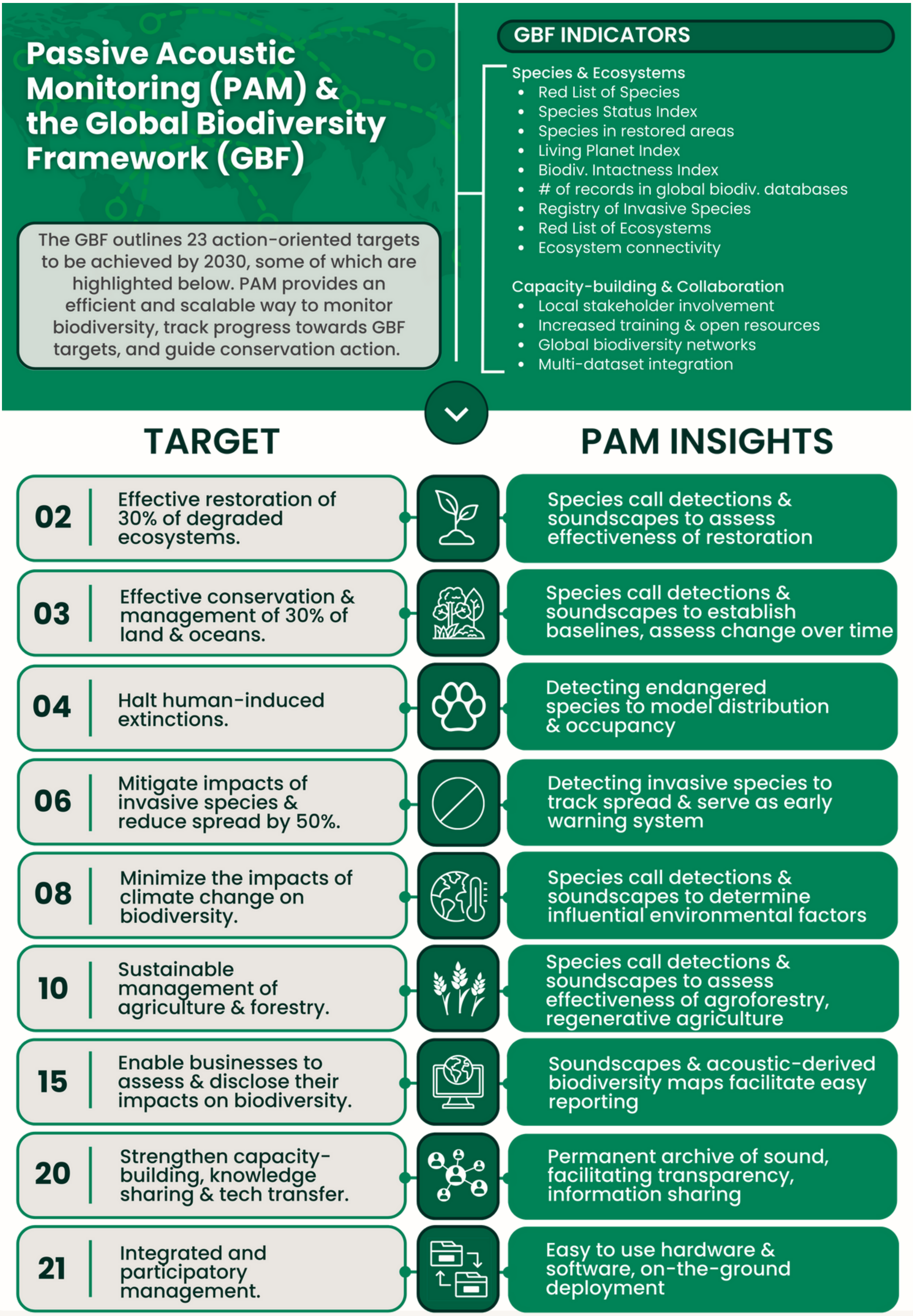
### Box 1. Rainforest Connection and Arbimon

At Rainforest Connection, we focus on real-time threat detection of illegal activities, such as logging and poaching, using acoustic technology. To decrease illegal activity and protect threatened ecosystems, we developed real-time recorders called Guardians, which are placed in the canopy and run in real time. The Guardians **can automatically detect the sounds of chainsaws or gunshots and send alerts to rangers or communities, who can then immediately take action to stop illicit activities.** Guardians can also be used to monitor biodiversity, but to increase spatial coverage we also utilize offline recorders for these projects.

**With Arbimon, we harness the power of AI combined with scalable and repeatable data collection practices to enable comprehensive assessments of biodiversity patterns and ecosystem health.** Arbimon provides powerful ecoacoustic services for stakeholders to transparently access ecological and conservation insights over space and time. Our AI models automate species detections and translate acoustic data into biodiversity insights, enabling data-based decision-making. Our user-friendly, cloud-enabled platform aims to bridge the gap between research, management and implementation to drive conservation action on the ground and across the globe. **Arbimon is the largest digital archive of soundscapes in the world,** hosting >230 million recordings from 119 countries which have been used to detect and identify 3,800+ species.

**Combined, these biodiversity monitoring and threat detection streams allow us to deliver a holistic approach that drives meaningful decision-making and conservation.**

Figure 3. How PAM insights can inform GBF targets and indicators



# Case Studies

## Tracking Restoration Progress

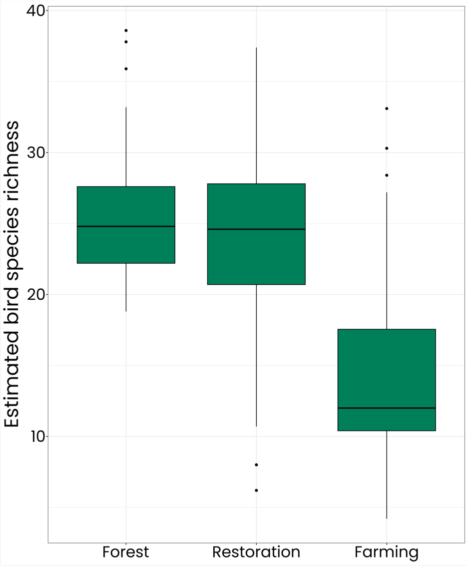
Global-scale ecosystem restoration is urgently needed as human land-use activities have severely degraded many ecosystems. Restoration can help repair these damages, recover lost biodiversity, and enhance the resilience of ecosystems to future disruptions. GBF Target 2 mandates the effective restoration of 30% of degraded ecosystems by 2030. However, restoration can only be considered effective if biodiversity is restored to a benchmark or baseline level. RFCx has partnered with WeForest and IPÊ to assess and monitor biodiversity in Atlantic Forest restoration areas using PAM. In the first two years of the project, we detected 187 species across 120 sites, including threatened species such as black lion tamarins and bare-throated bellbirds that are found only in the Atlantic Forest.

Our results indicate that restoration sites have a positive effect on biodiversity by increasing available habitat quality and facilitating connectivity between forest fragments. We found that restoration sites are able to host a similar number of bird species as protected forests (Figure 4), which is higher than species richness in farms. However, restoration and forest sites did have slightly different species compositions (e.g., types of species present). Specifically, restoration sites had more generalist species, while some specialists such as **frugivores** were still only found in primary forests. This emphasizes the need for long-term management efforts to allow restoration sites to fully transition back to benchmark biodiversity levels.

**Frugivore**
An animal that eats primarily fruit

Bare-throated bellbird
(*Procnias nudicollis*)
Photo Credit: Alessandher Piva

Figure 4. Species richness is similar in primary forest and restoration sites in the Brazilian Atlantic Forest.



# Case Studies

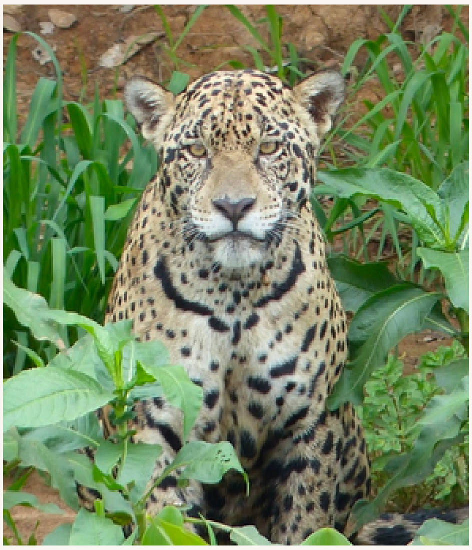
## Managing Protected Areas

GBF Target 3 asserts there must be effective conservation and management of 30% of lands and oceans by 2030 (commonly referred to as the "30x30" target). Protected area management must take an ecosystem-wide approach to monitoring, and integrating datasets from different methods or sensors is a fruitful way to achieve this comprehensive sampling. Many conservation technologies are complementary in which species they detect, and can be used in conjunction.

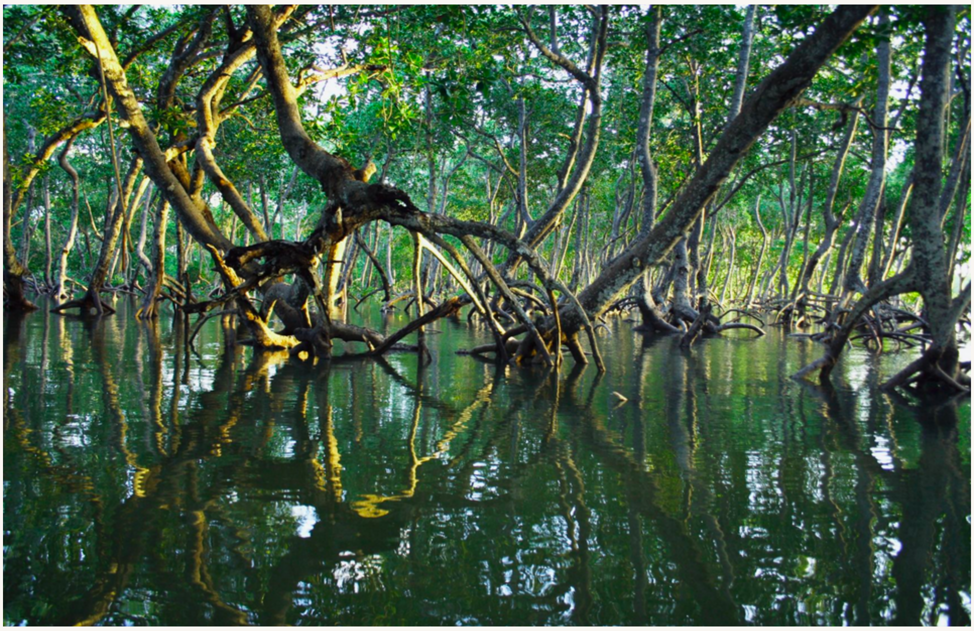
RFCx is collaborating with C Minds, IUCN, Huawei Mexico and local communities to monitor biodiversity in Dzilam Reserve, Yucatán, Mexico using camera-trapping and acoustic monitoring. The extensive mangroves in the **RAMSAR**-designated reserve offer a unique habitat for terrestrial and aquatic species alike, while also providing a natural buffer against increasingly extreme hurricanes. Using acoustic monitoring, we detected 95 species across 30 sites, including the elusive jaguar and the endangered Geoffroy's spider monkey.

We found that species richness was positively correlated with low-forest cover, meaning that a higher number of species were detected in areas with higher proportions of forest. We also found significant variation in soundscapes across different seasons, demonstrating both spatial and temporal influences on biodiversity in Dzilam. We are now integrating these results with insights from concurrent camera-trapping to more comprehensively understand how species utilize this protected area and inform management decisions.

**RAMSAR**
Wetland regions of high importance for species conservation (particularly birds)



Jaguar (*Panthera onca*)



## Case Studies

**Endemic**
Species found only in a specific region

**IUCN RedList**
Database and system for classifying species' risk of global extinction

### Halting Animal Extinctions

Protected areas play an essential role in conserving endangered and **endemic** species, some of whom are restricted solely to national parks or reserves. Target 4 of the GBF mandates a halt to human-induced extinctions and conservation of endangered species. Passive acoustic monitoring can be used to monitor the status of endangered species and track their recovery, which are critical metrics for achieving this target. Ecoacoustics is an ideal method for surveying elusive or endangered species because acoustic sensors are non-invasive and run autonomously. In the Galapagos islands, RFCx is working with the Charles Darwin Foundation to monitor the Critically Endangered mangrove finch, a species with only 100 individuals left in the wild.

We trained a high-accuracy AI model that is facilitating ongoing automated detection and monitoring of this species from their calls. These results are informing important work to understand where the mangrove finch is present across its historic range at sites distant from its main population sites. Many rare species are considered Data-Deficient by the IUCN RedList, meaning that there is not enough information to properly assess a species' risk status. It is vital that we integrate data from different sources, such as sensor technology and traditional knowledge, to build as comprehensive an understanding as possible of rare species' distributions. This will reduce the number of Data-Deficient species and facilitate up-to-date risk statuses and action plans.


Mangrove Finch (*Geospiza heliobates*)
Photo credit: Charles Darwin Foundation

## Case Studies

### Mitigating Invasive Species

A driving factor behind many species' extinction risk is the introduction of invasive or alien species. Invasive species can significantly impact biodiversity by outcompeting native species for resources, preying on them, or introducing new diseases. The increase and spread of invasive species can result in a loss of biodiversity, disruption of ecological processes and degradation of ecosystem services. GBF Target 6 states that invasive species spread must be minimized by at least 50%. Ecoacoustics can be used to detect the presence or spread of invasive species, acting as an early warning system to trigger management interventions.

For example, RFCx is working with the University of Bristol and the Mammal Society to assess the effect of invasive grey squirrels on native red squirrels. Red squirrel populations have sharply declined in the UK due to competition and disease from the grey squirrel. Our in-country partners are leading red squirrel reintroduction efforts and adaptively managing grey squirrel populations. To facilitate this, we created a high-precision AI model to automatically identify the calls of these two species in real-time. These findings will facilitate adaptive management by detecting the spread of grey squirrels and identifying priority conservation areas for red squirrels.

Red squirrel (*Sciurus vulgaris*)
Photo credit: Mammal Society

# Case Studies

## Promoting Sustainable Land-use Practices

Sustainable land-use management is the focus of many GBF Targets (1, 10, 11, etc.). The data collected through PAM can inform conservation planning and land-use decisions, as well as provide baseline data for assessing the effectiveness of management interventions. For example, we worked with the World Wildlife Fund to evaluate the impact of Forest Stewardship Council (FSC) management on biodiversity in the Tahuamanu region of Peru. We used PAM to survey 220 bird species across three forest types: 1) FSC-regulated sites, 2) unregulated forest sites, and 3) primary forests (used as a benchmark). We found that FSC-certified sites displayed a greater soundscape diversity compared to uncertified logging areas and bore a closer resemblance to pristine forest.

These results suggest there is greater **soniferous** species richness in FSC sites than unregulated sites. This shows that forest certification can sustain both biodiversity and sustainable livelihoods. These findings are being leveraged to promote and broaden FSC's global forest certification programs. Recent policy initiatives have placed a much-needed and overdue emphasis on corporate sustainability and mandated nature-related disclosures (**TNFD**, **EU Taxonomy**). In light of these new regulations, it is vital for companies to measure their environmental impacts and understand how commercial activities affect biodiversity. Ecoacoustics is a powerful way to fill this knowledge and monitoring gap within the private sector.

**Soniferous**
A sound-producing species or object

**TNFD**
Taskforce for Nature-Related Disclosures; a risk management and disclosure framework for organizations to report and act on evolving nature-related risks

**EU Taxonomy**
European Union-wide classification and transparency framework for sustainability; includes the Corporate Sustainability Reporting Directive (CSRD) and Sustainable Finance Disclosure Regulation (SFDR)

Chestnut-eared araçari (*Pteroglossus castanotis*)
Photo Credit: Tomaz Nascimento de Melo

# Case Studies

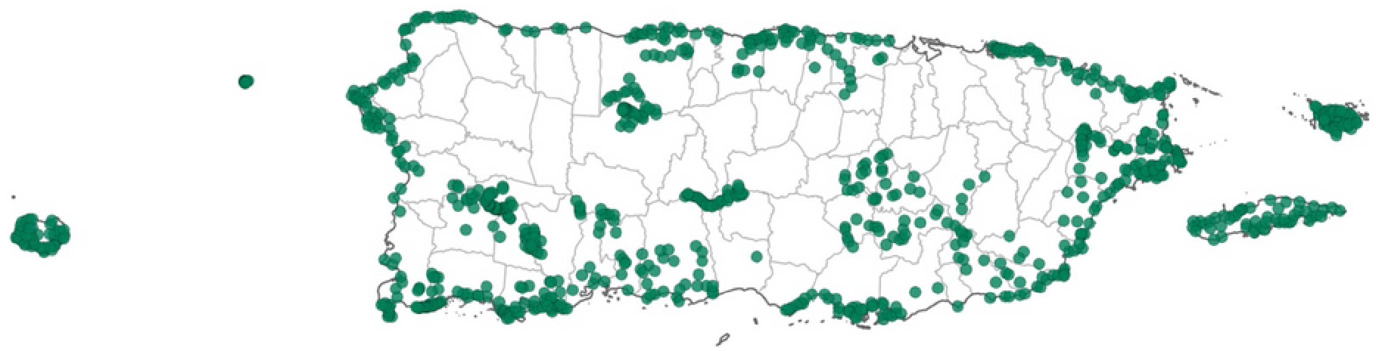
**Refugia**
an area where specific environmental circumstances have enabled a species or population to survive after extinction in surrounding areas

## Identifying Climate Change Refugia

Target 8 of the GBF states that we must minimize the impacts of climate change on biodiversity. PAM can inform the indicators for this target by identifying changes in species composition, behavior, and distribution that may be influenced by climate change. Acoustic detections can be coupled with environmental and climatic variables in ecological models to predict species responses to climate change and global warming. As the scale of natural disasters increases, PAM can also be used to assess species' responses to extreme weather events such as hurricanes. This information can support the development of effective climate change mitigation and adaptation strategies for conservation. We have put this into practice in Puerto Rico, working with government agencies and local NGOs to evaluate animal responses to climatic variables and model expected species range shifts under climate change scenarios.

We have implemented island-wide sampling with >900 deployment sites, and integrated this PAM data with environmental and climatic variables (Figure 5). Our results indicate that the distributions of many bird and frog species are shifting towards high-elevation areas due to climate change. We found that drought had a stronger negative effect on bird communities than hurricanes. But with Puerto Rico expected to become dryer under current climate change scenarios, animals will likely be forced to shift their ranges in search of forest cover. Our results demonstrate a mismatch between current protected areas and remaining suitable bird habitats under climate change scenarios, emphasizing the need for larger, more connected protected areas. Our local partners are now using this information to establish new corridors and reserves that better align with expected species range shifts.

Figure 5. Map showing the 900+ sites where acoustic recorders were deployed across the Puerto Rico archipelago.



# Case Studies

**Anthropogenic**
Resulting from human activity

**ICD Framework**
Combining conservation efforts with sustainable development strategies to promote both environmental protection and local/indigenous community well-being  participation

## Monitoring **Anthropogenic** Risks

There is an urgent need to develop sustainable land-use practices, livelihoods, and supply chains that benefit both people and nature. It is these **integrated conservation and development (ICD)** policies and initiatives that enable long-term sustainable development. The corporate sectors must improve their nature reporting, disclosure practices, and transparency. GBF Targets 14 and 15 require businesses to develop nature-positive policies, as well as assess and disclose their impacts on biodiversity. PAM can be used to study how extractive or commercial activities impact biodiversity, to inform corporate disclosures and policies. For example, we worked with South American universities to examine the impact of an artisanal gold mine on bird and frog communities in Tambopata National Reserve, Peru.

We found that birds sensitive to disturbance are missing from areas of active mining due to habitat degradation and noise pollution. Even abandoned mining sites could not sustain the range of bird species found in forest sites. In contrast, frog species richness was highest in the active mine and lowest in the forest, demonstrating that not all taxonomic groups respond to **anthropogenic** activities the same. This emphasizes the importance of considering conservation initiatives that account for taxa-specific responses. Animal species may react variably to different anthropogenic activities; for example, species may be more or less sensitive to mining versus logging versus roads. It is important to take such considerations into account when mitigating the effects of commercial activities.

Paradise tanager (*Tangara chilensis*)
Photo Credit: Tomaz Nascimento de Melo

# Case Studies

In addition to mines, dams and hydroelectric projects have significantly harmed ecosystems by submerging forests, altering river flows, and disrupting nutrient cycling processes. These impacts have severe consequences for associated biodiversity, ecosystem services, and the livelihoods that depend on them. We worked together with USAID, Brazilian institutes and American universities to evaluate how a dam in the Madeira River, one of the largest tributaries of the Amazonas River, impacted biodiversity. We recorded 195 bird species across all sites, but found that species composition differed significantly upstream and downstream of the dam.

Specialist species appear to have been replaced by more generalist and widely-distributed species in upstream sites as a result of damming. Biodiversity surveys conducted before dam construction showed similar species composition and vegetation cover across sites, confirming the dam as the likely driver of this change. The most concerning finding from this project was the local extinction of forest specialist species. The impact of the dam on the bird community depended on the habitat affinity of each species, but there appears to have been a connectivity loss between upstream and downstream populations.

Band-tailed manakin (*Pipra fascicauda*)
Photo Credit: Tomaz Nascimento de Melo

# Case Studies

## Centering Indigenous Communities

The GBF places a much-needed and long-overdue emphasis on engaging and empowering Indigenous communities in biodiversity conservation. This is underscored by numerous studies demonstrating the high effectiveness of Indigenous-led conservation that incorporates traditional knowledge. Targets 21 and 22 require equitable representation and participation of Indigenous peoples and local communities in conservation decision-making and GBF implementation. As such, RFCx is working in partnership with the Tembé people to assess biodiversity on the Indigenous Lands of Alto Rio Guamá, Brazil. Using PAM, we detected 211 species across 136 sites, including 21 endemic and 24 endangered species.

This project resulted in the first observations of two bird species in Maranhão state, expanding their previously-known distribution. The presence of many endemic and threatened species demonstrates the vital role that Indigenous Lands play in Brazilian conservation. It is critically important that we acknowledge and support Indigenous communities in their long-term monitoring efforts, which contribute integral information to our understanding of data-deficient and endangered species. In addition to biodiversity monitoring, we further support the Tembé in their goal of eradicating illegal logging from their lands. We have collaborated with them to implement our Guardian system (Box 1) which alerts community members when chainsaw sounds are detected in their lands.


Photo: Tembé memebers deploying autonomous audio recorders.
Photo credit: Tembé community

# Case Studies

## Detecting Threats in Real-Time

Acoustic monitoring can be used to directly detect threats, such as logging or poaching, through proxies of these activities, like chainsaws and gunshots. RFCx's innovative threat detection system (Box 1) has been deployed in 23 countries to prevent illegal logging and animal poaching in real-time. RFCx partnered with Taytay-el Nido Protected Area and Huawei Philippines to deploy Guardians across five protected areas across Palawan, Philippines. Over 2 years, this system has generated >2,330 chainsaw alerts and successful stories of rangers apprehending illegal loggers.

We have also evaluated how well the RFCx system works in detecting logging by comparing the number of Guardian alerts with the number of deforestation alerts generated by Global Forest Watch (GFW). Our results from Brazil and Sumatra show that in all of our study areas, the overall number of GFW alerts decreased throughout the course of the project, suggesting a reduction in deforestation rates. The Guardian system was also able to pick up on early, small-scale deforestation not detected by satellite imagery, highlighting the early-warning ability of the RFCx system.

Photo: Guardian recorder for real-time threat detection.

# Key Takeaways

The GBF outlines ambitious, yet necessary, targets for preserving and restoring biodiversity worldwide. **Achieving the GBF targets requires effective monitoring and assessment tools to track progress and guide conservation actions.** The combination of PAM and AI holds great potential for implementing the GBF and achieving its targets. This innovative approach is a non-invasive, cost-effective and scalable solution for monitoring biodiversity and supporting evidence-based decision-making to safeguard ecosystems. PAM yields systematic and comprehensive data for assessing biodiversity trends, providing up-to-date data for informed decision-making and adaptive management.

Ecoacoustics can also be combined with additional technologies, such as camera-trapping, eDNA, drones, and other sensors, to build a comprehensive understanding of biodiversity patterns and trends. Many of these methods are quite complementary and can capture unique sets of species, so using them in combination with one another is a very promising avenue moving forward.

However, integrating and harmonizing data from different sources can be challenging. Ensuring platform interoperability and standardized data formats will be important for effectively combining multi-sensor datasets in AI and ecological models. Furthermore, sound is a powerful communication tool and can help raise awareness about the importance of biodiversity conservation. By engaging the public in monitoring efforts, researchers can help build a sense of community ownership over biodiversity conservation and encourage individuals to protect the natural world.

It is essential that we explore and implement innovative approaches to address the challenges facing our planet. **Ecoacoustics offers an effective and scalable means of monitoring biodiversity that can help us achieve our conservation goals and ensure the sustainability of our planet.** We have the tools and the knowledge to improve monitoring at a global scale and halt the current biodiversity crisis. By leveraging this technology, we can make meaningful progress towards the protection and preservation of our natural world.