Barun Biomeridian Research Project

Informing Sustainable Community Adaptation to a Changing World

Two-Year Progress Report

(April 2019 - March 2021)

Team member installing SM4 bioacoustics and meteorology data logger in the study area

The East Foundation

Future Generations University

Barun Biomeridian Research Project

Two-Year Progress Report

Globally Vulnerable and nationally Data Deficient, Mainland Serow *(Capricornissumatraensis)* descending down to lower elevation during the heavy snowfall in the Bagare (2909 m elevation) on 15 December 2019.

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Executive Summary

The Barun Biomeridian Research Project pioneered a new method to understand ecosystem change in today's changing world. The method uses bioacoustic monitoring across an elevational transect of habitat diversity (a biomeridian). By listening to birds, the first three years of research findings appear to show soundscapes across landscapes may be a valid way to understand our changing world. This is a report on the exciting first phase in Nepal of what is a global research project with teams from Nepal, Bolivia, and USA.

Around the world, the balances of life are changing rapidly due to climate change. Mountain communities are at the center of many of these changes. These changes affect people's lives, and indeed all forms of life are having to adapt. To facilitate informed adaptation to climate and anthropogenic change, communities need to be informed about what is happening in their specific areas, then engaged in learning how they can begin a process of steady adaptation where the result is for the quality of their lives to improve.

Two aspects are needed. First, local communities need to understand the implications of global climate change. The global picture must be made comprehensible with local level data. Second, local communities need to learn how to continually adapt so that they are advancing the quality of their lives and helping protect the natural balances of all life. The Barun Biomeridian Research Project in Makalu-Barun National Park provides scientific evidence and an educational foundation for community-led adaptation.

One method of identifying local climate change is through the study of biomeridians that span multiple elevations and ecosystems. These transects provide the opportunity to observe how local plants and animals adapt to changing temperatures and weather patterns. The Barun Biomeridian Research Project monitors a transect along the Barun River, which travels from the Makalu glacier down to Barun Dovan, the confluence of the Barun and Arun.

Through this collaborative work, Nepal is at the forefront of global cutting-edge research on the use of bioacoustics to examine the effects of climate change. As part of the global Songs of Adaptation project, the Barun Biomeridian Research Project represents the first and most comprehensive Biomeridian, providing a standard for work in other areas of the world such as Madidi National Park in Bolivia and the Chesapeake Bay in the United States. Cross-sector collaboration among key partners models the potential for on the ground monitoring, high-tech analysis, and management specialists to collaborate and produce important impact that has relevance locally and globally as a scientific innovation to understand ecosystem change.

With technological advances, new tools are becoming available to assist stakeholders, local and global. The Barun Biomeridian Research Project uses birds—animals shown to be sensitive as indicators of climate change, and their sounds to determine if animals are

moving to higher elevations to adapt to changing conditions. Bioacoustics equipment records five-minute sound clips, multiple times a day, at eight stations along a transect spanning elevations of 1100 to 4000m. Bioacoustics allows us to go where human ears cannot stay and listen. Artificial Intelligence-enabled analyses are used to analyze the large volume of sound data, helping us identify results that can facilitate informed adaptation and management.

The Barun Biomeridian Research Project leverages these cutting-edge technologies to monitor birds and habitats for biodiversity research and long-term climate change analysis. The overall goal is to use bioacoustics to show the effects of climate change on birds in MBNP and use this information to partner with communities to understand and adapt to changing conditions. Assessing the effects of climate change will be long-term project, but already available are important information about species presence and distribution, climate, and ecosystem characteristics. The success of the project relies on a strong existing partnership between citizens, educators, community leaders, government officials, and scientists.

This two-year progress report outlines the activities and accomplishments of the Barun Biomeridian Research Project, April 2019-March 2021. With this report we also seek renewal of permissions for this project to continue for an additional three years (as per the five-year proposal originally submitted). The sections of this report are described below, and Annexes listed in the report can be found in electronic format on the accompanying hard drive.

- Section 1 provides an overview of the project justification and novel Biomeridian concept for climate change monitoring. An overview of the global Songs of Adaptation project is also included.
- Section 2 includes an in-depth description of the Barun Biomeridian monitoring sites and the data collected.
- Section 3 shares the results of wildlife camera trapping activities.
- Section 4 explains the bioacoustic data analysis framework developed as part of the Songs of Adaptation project. The EarthHz user interface for data listening, labeling, and visualization of model results is explained.
- Section 5 describes the ongoing bioacoustic data analysis which has been completed thus far.
- Section 6 describes the community centered works that were conducted as part of this project, including efforts of The East Foundation to provide climate change awareness and training to people who live near the research project area.

- Section 7 summarizes the main conclusions and achievements of this project and outlines potential next steps.
- Appendices include previous reports and supplementary materials.

1 Introduction

1.1 Climate Change Urgency

Scientific literature-based assessment on atmospheric and surface climate observations reported that the global mean surface temperature has increased since the late 19th century, and the decade of the 21st century has been the warmest (Hartmann et. al., 2013). The temperature and precipitation changes in the same period is not the same in all regions, and the trends differ at different altitudes in the same region. Studies conducted by the International Centre for Integrated Mountain Development (ICIMOD) revealed that there is an increased magnitude of warming (0.01 to 0.060 °C/year) with elevation in the eastern Himalaya (Sharma et. al., 2009).

Climate change creates an urgent need to understand whole ecosystem processes because many parts of nature and humans must adapt to changing conditions at the same time. This time of dramatic change in many of the world's ecosystems is leading to tremendous habitat and biodiversity loss. Retaining biodiversity and adapting to and mitigating climate change are paramount problems of this generation.

Natural vegetation has already been exhibiting response to global warming through structural changes of forest and vegetation. These changes lead to the creation of negative impacts on agriculture and food security, water resources, forests and biodiversity, health, tourism and infrastructures, and ultimately to reduce adaptive capacity and increase vulnerability of communities and ecosystems.

Climate change is global phenomena but people at each locale must face the negative impact of climate change while they act as the users and guardians of nature and its resources. Around the world, the balances of life shift due to climate change. To facilitate informed adaptation to climate and anthropogenic change, communities need to be informed about what is happening in their specific areas, and then engaged in learning how they can begin a process of steady adaptation where the result is for the quality of their lives to improve.

1.2 Biomeridian Concept

A mountain slope encapsulates the natural diversity ranging from tropical to polar conditions, mirroring latitudinal shifts in vegetative and animal complexes within short vertical distance. Mountain communities are, therefore, at the center of many of the effects of climate change.

Traditional laboratory scientific observations of change use a control which does not change or baseline observations before change occurs. As the earth undergoes climate change, there is no control. And in many places change is already occurring without baseline observations in place to document the original state.

A *biomeridian*, or biological meridian measuring change across a gradient, is a measurement framework for complex adaptive systems of ecology and their responses to climate change. By observing along a biomeridian, we gather information across a range of states to infer past and future states, substituting for a control or baseline data. A biomeridian can elucidate change and allow extrapolation of changes by looking along the gradient transect.

The first biomeridian case study for the Songs of Adaptation Project is located in the Makalu-Barun National Park, Nepal, an important global biodiversity hotspot. The larger objective is to formulate an observational framework which allows scientists and communities to understand whole ecosystem change in many locations and adapt to the coming climate crisis; Nepal is now leading this effort through the Barun Biomeridian Research Project.

1.3 Global Songs of Adaptation Project

The Barun Biomeridian Research Project is part of a global research project of Future Generations University called Songs of Adaptation. Over the last few years, FGU has built a network of monitoring in some of the most biodiverse and venerable regions of the world, led by the Barun Biomeridian Research Project in Makalu-Barun National Park in Nepal.

Day and night data are collected-- audio, camera, temperature, and humidity data. Data analysis provides information for increasing global understanding of how human activity is affecting natural systems. Short-term impacts include helping local stakeholders and scientists to better understand species distribution and behavior, and the engagement of local communities. In the long-term, this project will document ecosystem shifts due to climate change.

Despite a planet overflowing with large datasets, adequate tools do not yet exist to inform understanding of local change. Bioacoustics allows us to go where human ears cannot stay and listen. Artificial intelligence analysis leads to fast insights, facilitating informed adaptation. Songs of Adaptation builds on established community partnerships globally. Leveraging technology for research and action, this project serves to preserve swiftly disappearing voices of nature and local knowledge alike (see Figures 1 and 2).

Acoustic recordings document biodiversity by exceeding what would normally be captured by human ears or camera traps. Focus thus far has been on birds because they instinctively adapt to the natural world as they travel across ecozones and seek optimal food and habitat. MBNP is at the edge of the ranges of many bird species. Therefore, species may be common in other countries, such as Bhutan, yet rare or near extirpated from Nepal.

BirdLife International lists 348 bird species as having been found in the MBNP (http://datazone.birdlife.org/site/factsheet/14338). Many bird species are particularly sensitive to habitat disruption, declining food sources, pollution, temperature change, and shifting plant varieties. We hypothesize that birds respond to climate change and their movement and distribution will help demonstrate the progression of climate change, helping local communities understand how quickly these changes are occurring and what ecosystems and resources are most threatened. A primary goal of this project is to connect local communities and stakeholders with global scientific and technology resources, returning data insights that are relevant to continued conservation action, thereby increasing resiliency and informed adaptation during this climate crisis.

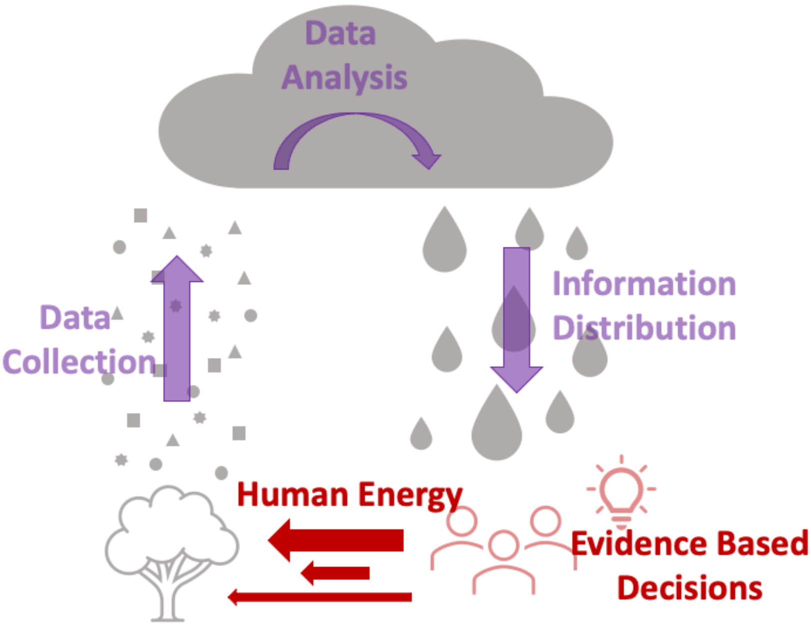

Figure 1: This project observes ecosystem data and uses cloud-based data storage and analysis to convert this data to usable information. This information is distributed to stakeholders locally and globally to assist in evidence-based decision making.

In addition to the Barun Biomeridian described in this report, monitoring is ongoing in Bolivia and the USA.

USA - In the United States' Appalachian region, Songs of Adaptation monitors a Spruce forest, meadow sites, eastern hardwood forests, and a stream restoration site. School children are involved in monitoring vegetation and learning about these diverse ecosystems. Successes this year at these sites include developing local partnerships, curriculum development, and student engagement. Sites nearby FGU headquarters allow testing of instrumentation and new methodologies. These monitoring areas are located in the headwaters of the Potomac River, approximately 652 km long, with a drainage area of about 38,000 km^2. Tributaries of this river drain Spruce Knob, the highest mountain and an ecologically important area in the State of West Virginia. The river flows through several states, through Washington DC, the capital of the US, and feeds the Chesapeake Bay, the largest and one of the most important estuaries in the United States. The river provides drinking water to many cities, irrigation for farms, along with recreation and fishing.

At a stream restoration site in the USA, the stream is now being protected by a riparian buffer strip which is expected to provide increasing habitat for birds and amphibians in just a few years. The potential for monitoring habitat restoration sites around the world is immense.

Bolivia – In Bolivia, Songs of Adaptation monitoring stations are installed in and near Madidi National Park. This region is among contiguous protected areas in Bolivia and across the border into Peru. Deforestation is one of the biggest environmental changes occurring in Northern Bolivia. As land outside of the protected areas is altered by humans and stripped of forests, it is possible that the wildlife populations may shift their ranges. The singular monitoring station would record these changes over time. If temperatures are shifting over time, then species may shift up altitude gradients. These changes would be recorded by the biomeridian installation.

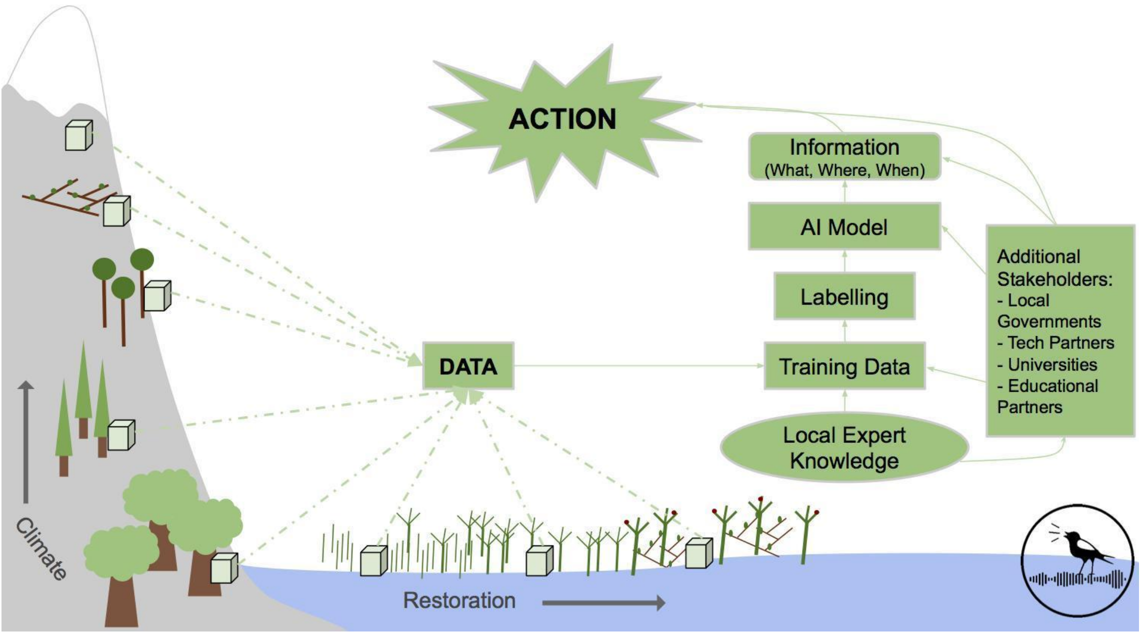

Figure 2: Data collected from different ecosystems along a biomeridian (e.g., an elevational gradient or restoration gradient) and analyzed to inform evidence-based action.

1.4 Barun Biomeridian Formation

To establish an international network of biodiversity monitoring transects–arrays of instrumentation stations along mountain transects, FGU chose Barun Valley in Nepal, and developed partnerships with local communities and collaboration with The East Foundation (TEF), a local NGO. Barun Valley is one of Nepal's most biodiversity-rich pristine valleys located in the Makalu-Barun National Park (MBNP).

Long-term monitoring along this transect will lead to a continually growing understanding of how flora and fauna adjust to anthropogenic and climate change. On the other hand, combining data from scientific instrumentation with local knowledge informs people so they can evolve increasingly effective responses to ecosystem destabilization on a changing planet.

With the support and permission of the Department of National Parks and Wildlife Conservation (DNPWC), Government of Nepal, FGU and TEF conducted a preliminary feasibility study in the Barun valley in 2018. The study recommended a need of continuing the work for a long period of time. Hence, based on the feasibility study's findings and lessons learned, and fitting with the MBNP's management plan (2017-2022), a five-year plan proposal was developed which includes both scientific work and community engagement and trainings in order to meet the following primary objectives.

a. to utilize scientific observations along transects to establish a baseline for biodiversity upon which changes due to climate change and anthropogenic effects can be monitored;
b. to examine biodiversity and changing dynamics using sound;
c. to develop deep partnerships with local communities as co-equal investigators and users of the resulting data; and
d. to provide training to encourage the development of the socio-ecological resilience and adaptive capacity of local communities in a changing environment.

The proposal was submitted to DNPWC for the permission to conduct the plan for five consecutive years as the Barun *Biomeridian Research Project*. The Government granted permission for 2 years to be effective from April 2019. As per the agreement, Project's achievement reports (April 2019 to September 2019 – see Annex 2, Figure 3) and (October 2019 to March 2020 – see Annex 3) have been submitted to DNPWC, and a presentation was also performed at the department's premises in November 2019.

The global pandemic COVID-19 influenced the project's second year works. Despite this, field technical staff made a series of trips to the plots/stations to download the meteorological, bioacoustics, and camera trap data. As per the need to submit a two-year progress report at the end of the project period, this report has been prepared as follows.

Figure 3: Project's achievement presentation in DNPWC, 2019

2 Scientific Summary

2.1 Site Description

Makalu-Barun National Park (MBNP) covers an area of 1,500 km^2 and its buffer area covers 830 km^2, is a unique protected area with an elevation gain of more than 8,000 m. This project is monitoring a transect along the Barun River (see Figure 4), which travels from the Makalu glacier down to Barun Dovan, the confluence of the Barun and Arun Rivers. The watershed spans over 472 km^2 and includes a number of tributaries, including Saldima Khola.

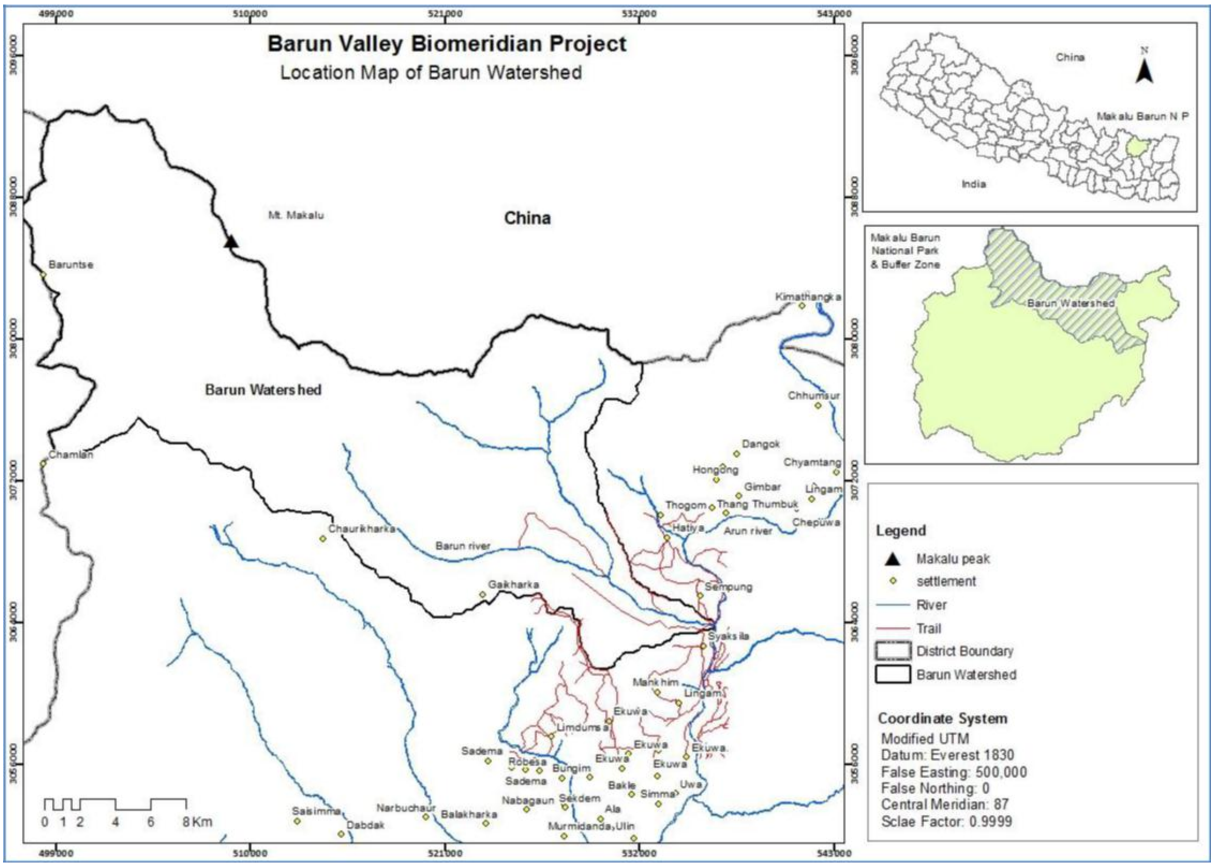

Figure 4: Location of the Barun Watershed in Nepal

Dobremez and Shakya (1975) had determined 500 m altitudinal interval as lifezone ecotone based on 250,000 scale study (Table 1). The next section of the report shows a list of permanent field monitoring sites. It is this project's global policy to not publish exact locations in order to minimize the ability to track wildlife at a specific location.

Overall Makalu-Barun valley protects a broad range of Eastern Himalayan forest types, ranging from near-tropical dipterocarp monsoon forest (400 m) to subalpine conifer stands (4,000 m). Forests span five bioclimatic zones (tropical, subtropical, lower and upper temperate, and subalpine), but ecotones are poorly defined. Below 2,000 m forests are strongly affected by subsistence agriculture, although some ecologically significant stands remain at those elevations. Above 2,000 m, a cool, humid climate suppresses agricultural activity and forests are usually extensive. An interesting transition occurs in the temperate zone from forests dominated by broadleaf evergreen (Quercus-Lauraceae) to broadleaf deciduous (Acer-Magnolia) taxa. Subalpine stands show an increased dominance by conifers (Juniperus, Abies) along a transect from outer, southern slopes to the inner valleys.

Aspect is ecologically important at all elevations, but controls different ecological variables (seasonal moisture availability, temperature, snow cover) at different elevations. The Makalu-Barun area exhibits the high regional diversity expected of a physiographically complex, low-latitude mountain region. The main ecosystem types that exist in Barun valley are river, freshwater, wetlands, forest, desert, grasslands and mountain making it unique for the biomeridian study.

Table 1: Main forest types inthe Barun watershed

Bioclimatic /ecological zones	**Altitude (m)**	**Major forest types**
Lower subtropical	1000-1500	*Schimawallichii, Castanopsis indica* forest
Upper subtropical	1500-2000	*Castanopsis tribuloides* pure forest or mixed with *Schimawallichii, Rhododendron arboreum, Lyonia ovalifolia, Eurya acuminate, Quercus glauca, Camellia kissi*
Collinean temperate	2000-2500	*Quercus lamellosa* forest with *Quercus lineata, Quercus glauca*, Lauraceae
Montane temperate	2500-3000	Deciduous mixed broad-leaved forest of *Acer campbellii, A.pectinatum, Sorbus cuspidate, Magnolia campbellii*
Lower subalpine	3000-3500	*Abies spectabilies* forest with *Rhododendron hodgsoni* and *R.barbatum*
Upper subalpine	3500-4000	*Betula utilis* forest with *Rhododendron hodgsoni, R.barbatum* and *Abies spectabilies*
Lower alpine	4000-4500	*Rhododendron-Juniper* shrubland with patches of abundant *Rhododendron anthopogan, R.setosum, R.nivale*
Upper alpine	4500-5000	Alpine slopes with Gramineae and Cyperaceae

Nival	Above 5000	Permanent snow and ice

Source: Dobremez and Shakya (1975)

2.2 Data Collection Foundation

2.2.1 Permanent Vegetative Plots

Barun valley covers a wide range of bioclimatic zones starting from subtropical to nival.A total of eight circular permanent plots each of 20-meter diameter were established at each bioclimatic zone and ecotone up to tree line along the biomeridian that stretches up along the Barun River from Barun Dovan (Figure 4; see Table 2). These vegetative plots coincide with the locations of climatic observations and bioacoustic recorder placement.

Vegetative plots were not established below Hinju Kharka (1800m) because of lying the land under private ownership. Two reference points have been set to detect each plot: one on the biomeridian trail and another at the centre of the plot. The former is denoted with a remarkable object while the latter with a tree but both are supplemented with altitude and geo-coordinates information (for detail see Annex 2: Project's achievement report April 2019 - September 2019).

2.2.2 HOBO Devices Installation

A total of eight HOBO data loggers (meteorological data recorders) were installed on the reference trees with one in each plot (Table 2). The loggers collect temperature and relative humidity data every 15 minutes, 24 hours a day.

HOBO MX2301 model loggers were installed in five stations while HOBO Pendant loggers in other sites. In November 2019, the MX2301 model loggers were upgraded to MX2301A, and HOBO Pendants were replaced with HOBO MX2301A (for detail see Project achievement report October 2019 to March 2020 – Annex 3).

Technical problems happened to appear in some devices now and then, and have been replaced with good if stock available otherwise sent to USA for repairing. As such, some of the broken equipment have been sent to USA.

2.2.3 Bioacoustics Devices Installation

Very remote regions pose a challenge for monitoring. Acoustic monitoring can continuously monitor large remote areas for avian community composition and tracking migratory and seasonal changes in populations.

At the permanent monitoring sites, bioacoustic devices (Wildlife Acoustics SongMeter4 recorders) were installed on the reference trees with one in each plot (Table 2). The recorders are programmed to record 5 minutes out of every 15 minutes from one hour before sunrise to one hour after sunset daily.

Table 2: Monitoring Site Locations, including non-active sites

Site Name	Land Ownership	Altitude (m)	Ecozone (Dobremez& Shakya, 1975)	Eco-region (Olson et al, 2004)	Data Type
Barun Dovan	Private	1260	Lower subtropical	Himalayan sub-tropical broadleaf forest	*not active (climatic, bioacoustic)*
Dhalima Ban	Community forest group	1567	Upper subtropical	Eastern Himalaya Broadleaf forests	climatic, bioacoustic
Hinju Kharka	National Park	1820	Upper subtropical	Eastern Himalaya Broadleaf forests	vegetation, bioacoustic, climatic
Kali Khola	National Park	2006	Collinean-temperate	Eastern Himalaya Broadleaf forests	camera trap
Bolangma Khola	National Park	2094	Collinean-temperate	Eastern Himalaya Broadleaf forests	*not active (camera trap)*
Deurali Danda	National Park	2100	Collinean-temperate	Eastern Himalaya Broadleaf forests	vegetation, climatic, bioacoustic
Tutin Kharka	National Park	2300	Collinean-temperate	Eastern Himalaya Broadleaf forests	vegetation, climatic, bioacoustic
Malinge Odar	National Park	2535	Montane-temperate	Eastern Himalaya Broadleaf forests	vegetation
Chyamlima	National Park	2512			camera trap
Ramite	National Park	2780	Montane-temperate	Eastern Himalaya Broadleaf forests	vegetation, climatic, bioacoustic
Ramite Danda	National Park	2818	Montane-temperate	Eastern Himalaya Broadleaf forests	*not active (camera trap)*
Dhap Khola	National Park	2894	Montane temperate	Eastern Himalaya Broadleaf forests	*not active (camera trap)*
Bagare	National Park	2909	Montane temperate	Eastern Himalaya Broadleaf forests	camera trap
Jante Odar	National Park	3235	Lower subalpine	Eastern Himalaya subalpine conifer forests	vegetation
Yangle Kharka	National Park	3680, 3882	Upper subalpine	Eastern Himalaya subalpine conifer forests	vegetation, climatic, bioacoustic
Ne Kharka	National Park	3700	Upper subalpine	Eastern Himalaya subalpine conifer forests	camera trap
Yak Kharka	National Park	4010	Upper subalpine	Eastern Himalaya subalpine conifer forests	vegetation, climatic, bioacoustic

In the beginning, the devices were loaded with a firmware ver. 2.0 which were updated to ver. 2.2 in May 2019. The devices were powered with internal Alkaline D-Batteries which needs to be replaced with new ones every 2/3 months interval. Due to the difficult terrain and adverse climatic conditions, it was difficult to replace the batteries in time. This warranted a need to replace the internal battery power system with an external one. As such, in November 2019, all the Alkaline D-Batteries driven system were replaced with external power systems of solar panels (for detail see Project achievement report October 2019 to March 2020 – Annex 3).

2.2.4 WildlifeCameras Installation

Four motion activated Browning trail cameras were installed at different elevations (see Table 2). These were located at different locations from the other instrumentation to meet best practices for wildlife monitoring via camera traps.

Some photos are embedded with the wrong date due to camera setup error, but all cameras were serviced and reset in November 2019. Additionally, the results of the initial camera trap analysis were used to reposition several wildlife cameras in November 2019 to locations more optimal to capture photographs of birds and mammals.

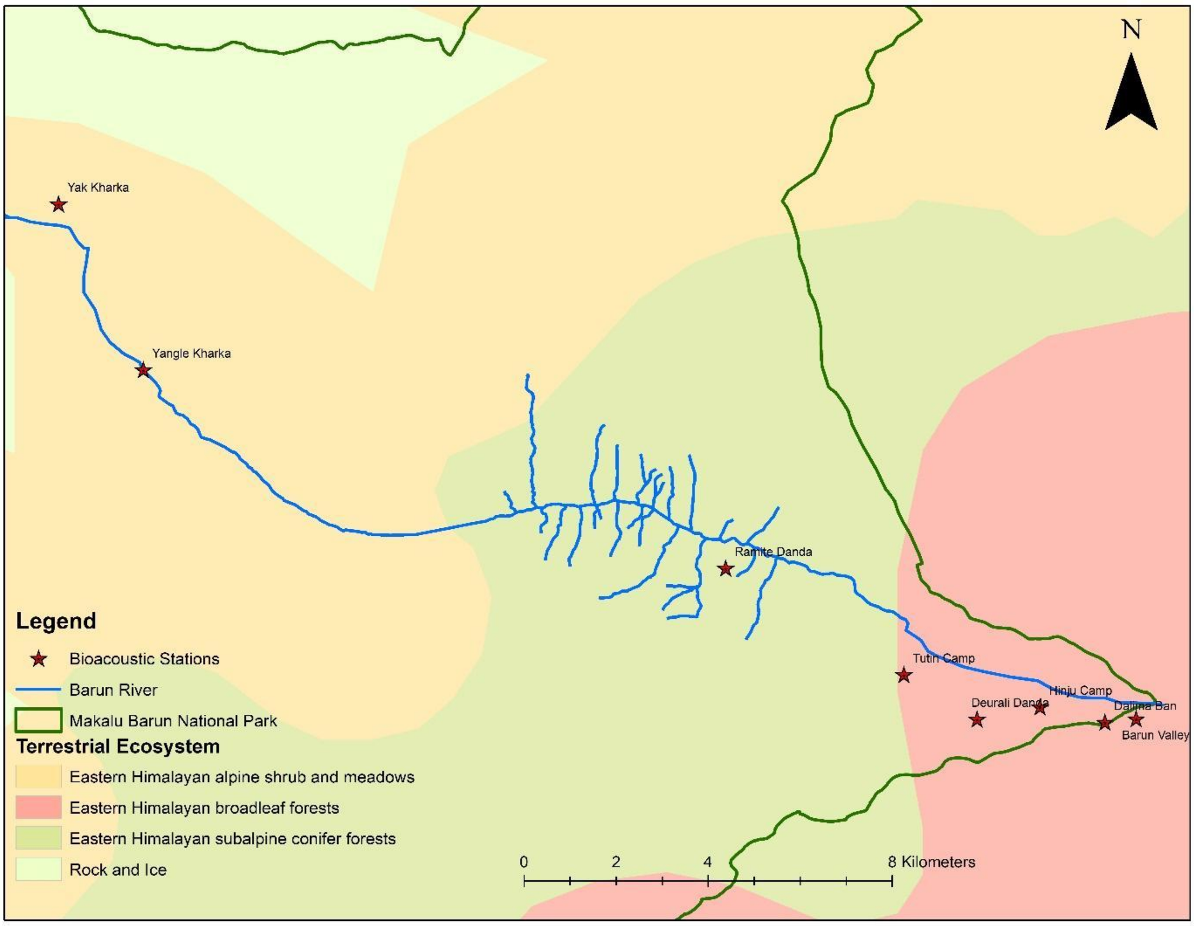

Figure 5: Bioacoustic stations along the Barun River with ecoregions extracted from Olson et al. 2004

2.3 Data Summaries

For more detailed descriptions of data analysis, please see Section 3 (Camera Trap Data), and Section 5 (Bioacoustic Data). Additional data summary tables are located in Annexes 5-8 and raw data files are located in Annexes 9-11 provided on the accompanying hard drive.

2.3.1 Ecological Data

General biophysical information in each plot has been collected. In addition, spatial and ecological (density, DBH, height and canopy cover) data of major canopy tree species within the plot has been collected. That accounts to 42 individual trees which belong to different species, genus and/or family (for a detailed report see Project's achievement report April 2019 to September 2019 – Annex 2). Data is scheduled to collect the ecological information at the interval of four years. General floral and faunal information along the trail were also collected.

2.3.2 Meteorological Data

HOBO loggers have been set to record the meteorological data at the interval of 15 minutes throughout the year. As such each logger does record about 35,000 records of data per year, but due to the occurrence of technical problems in some devices now and again and different installation date and time, volume of recorded data has differed from station to station and year to year. Recording was started from the time of preliminary study in 2018 at some sites in lower elevation while it was started at higher elevation in 2019. Last downloading at lower elevation was accomplished in January 2021 while it was in early October 2020 at higher elevation. So far, a total of 449,187 records of data have been collected from March 2018 to January 2021 (table 3), and the number of records by site and year is presented in Table 4.

Table 3:Volume of Temperature and relative humidity data by year.

Year	No. of records
2018	118675
2019	135660
2020	191226
2021	3626
Total	**449187**

Table 4: Meteorological dataset by site and year

Site	Year	No. of records
Barun Dovan	2018	28553
	2019	35045

	2020	35138
	2021	1765
Dhalima Ban	2018	23553
	2019	6494
	2020	26316
Hinju Kharka	2018	14709
Deurali Danda	2018	28564
	2019	35040
	2020	35136
	2021	1861
Tutin Kharka	2019	5122
	2020	26540
Ramite Danda	2018	23296
	2019	28344
	2020	14264
Yangle Kharka	2019	20881
	2020	26915
Yak Kharka	2019	4734
	2020	26917
Total		**449,187**

2.3.3 Bioacoustics Data

Bioacoustics devices have been programmed to record all sounds including that of birds, mammals, insects etc. of around its periphery for 5 consecutive minutes at the interval of 10 minutes from one hour before the sunrise to one hour after the sunset. Each 5-minute recording creates a file of about 27 MB in size. However, at a few stations the devices recorded almost an hour to make a single file ranging from 51.94 MB-285.33 MB (thus the large average file sizes in Table 4), but recording schedules were updated in November 2019 to correct this issue. As such, altogether 98,203 sound data files have been created so far which accounts to 2.793 TB (see Tables 5 and 6).

The reason for the low amount of data in 2020 is that data from the field has not yet been collected in the fourth quarter of 2020. For example, Yangle Kharka and Yak Kharka are located above 3600 m and are difficult and dangerous to access due to the rough snow cover terrain in the winter. Furthermore, the station in the Ramite Danda was swept away by the landslide, and due to technical difficulties, only a few stations were able to record a limited amount of data, and even though a limited amount of data was collected, it was still in the hands of the field staff.

Table 5: Volume of data recorded in each year in the study area

Year	Total no. of files	Files size (GB)
2018	39367	1172.36
2019	46666	1174.16
2020	12170	447.07
Total	**98203**	**2793.59**

Table 6: Bioacoustics data by stations (large average files sizes at some stations are due to longer recordings)

Site Name	Year	Number of files	File Size (GB)	Avg file size (MB)
Barun Dovan	2018	6460	172.9	26.76
Barun Dovan	2019	10274	274.1	26.68
Barun Dovan	2020	1151	30.8	26.76
Deurali Danda	2018	8524	228.3	26.78
Deurali Danda	2018	6231	167.9	26.95
Deurali Danda	2020	196	36.4	185.71
Dhalima Ban	2018	4580	237.9	51.94
Dhalima Ban	2019	4249	43.5	10.23
Dhalima Ban	2020	1388	33.6	24.19
Hinju Kharka	2018	7528	203.4	27.02
Hinju Kharka	2019	6471	172.9	26.71
Hinju Kharka	2020	3943	105.9	26.63
Lingam Banpale	2018	2796	74.7	26.72
Ramite	2018	4587	124.3	27.09
Ramite Danda	2019	8142	215.4	26.46
Tutin Kharka	2018	4892	130.9	26.76
Tutin Kharka	2019	4127	110.3	26.74
Tutin Kharka	2020	3497	90.9	25.99
Yak Kharka	2019	2243	59.4	26.50
Yak Kharka	2020	375	107.0	285.33
Yangle Kharka	2019	4929	130.6	26.50
Yangle Kharka	2020	1620	43.4	26.79
	2018-2020	**98203**	**2793.6**	

The variation of data volume by stations is due to the different installation date and time and to the technical problems occurring in the devices as in HOBO loggers. Technical issues included water damage, unreliable batteries, and damage from landslides.

3 Wildlife Camera Data

Four motion activated trail cameras (Browning, BTC-5HDP) were installed in six different locations (two were moved) (see Table 2 and Figure 6). These sites were Bolangma Khola (2,094 m), Kali Khola, Ramite Danda, Dhap Khola, Bagare and Yangle Kharka (two elevations). These sites were chosen based on the presence of animal signs. Camera traps were placed 30-45 cm above the ground. However, in those sites where winter snow covers this height, traps were placed higher. The traps were operated 24 hours a day and programmed to take single photographs per trigger.

All photos were manually sorted, and species identifications were done manually. A sequence of photographs of any species occurring after an interval of >60 minutes from the previous photograph was considered as an independent event when analyzing the data.

Table 7: Camera traps station, their elevation and number of photos and species in each station

Place	Elevation (m)	Total Photos	No of animal photos	No of Species
Bolangma Khola	2,094	16	4	1
Kali Khola	2,006	525	439	10
Ramite Danda	2,818	552	440	8
Dhap Khola	2,894	60	3	2
Bagare	2,909	51	44	5
Yangle Kharka	3,882	2,537	27	2

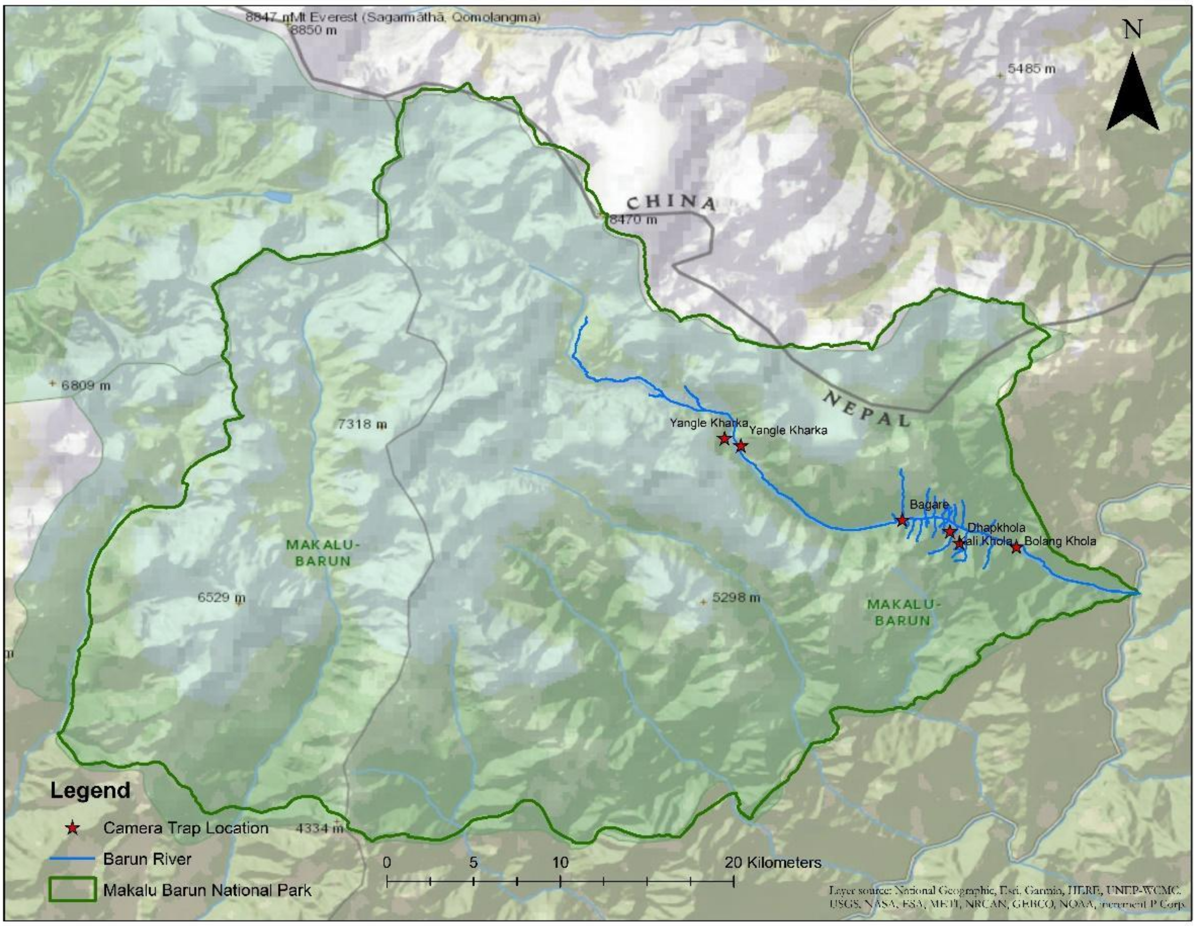

Figure 6: Camera trap stations in the Barun biomeridian along the Barun River

3.1 Wildlife Camera Results and Discussion

Altogether 3,741 photographs were obtained (See example in Figure 7) accounting a total of 1095camera traps night efforts. Among the photos, 2,728 were falsely triggered due to movement of vegetation or sunrays, 866 records were mammals, and the remaining 147 records were of birds, domestic cattle and unidentified mammals. See Table 7 for the number of photos taken at each site.

The survey recorded one globally Endangered species (Himalayan Red Panda *Ailurus fulgens*), two Vulnerable species (Himalayan Black Bear *Ursus thibetanus* and Mainland Serow *Capricornissumatraensis*) and three Near Threatened species (Himalayan Goral, *Naemorhedus goral Assam,* Macaque *Macaca assamensis,* and Himalayan Tahr*Hemitragusjemlahicus*). Moreover, in National Red List status Himalayan Red Panda, Spotted Linsang *Prionodonpardicolor*, Himalayan Black Bear are Endangered category, Northern Red Muntjac *Muntiacus vaginalis*, Assam Macaque, Leopard Cat*Prionailurus bengalensis* are Vulnerable species while Himalayan Goral and Himalayan Tahr are Near Threatened species. Moreover, Mainland Serow, Red Fox *Vulpes vulpes*, Royle's Pika *Ochotona roylei* are data deficient species nationally (Jnawali et al. 2011 and Amin et al. 2018) (Table 8).

Figure 7: Globally Vulnerable Himalayan Black Bear recorded in the Bagare at the elevation of 2,909 m.

Of the 866 photos of mammals, 18 mammalian species were recorded by the camera traps (Table 8). A few species could only be identified up to family level instead of species. Himalayan Goral (Independent Events IE 71) is the species having the highest number of records followed by Mainland Serow (IE 32), indicating the two most abundant species in the survey stations (Figure 8). Geographical conditions and steep terrains favor these two species along with a camera trap site in the Kali khola located on the mineral licking site where three species including Northern Red Muntjac regularly visit. However, Spotted Linsang, Himalayan Black Bear and Yellow-throated Marten *Martes flavigula*are only recorded from a single station having single independent events (Table 8).

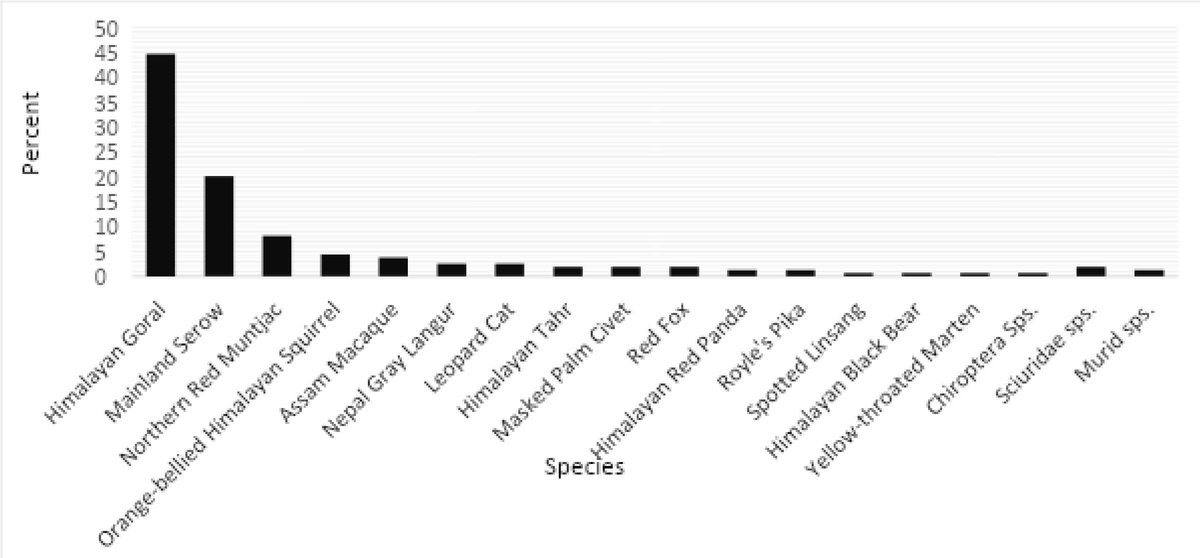

Figure 8: Showing the species recorded in Barun valley and Independent event in percentage

Among all the species, the record of Himalayan Red Panda from Bagare and Yangle Kharka could be the new locality of the species in Makalu Barun National Park. Both areas were undisturbed by human activity so natural ecological behavior of the species could be studied in future in these locations.

Moreover, photographic evidence from all the camera trapping sites shows few predators in the regions; Leopard and Clouded Leopard are notable lacking from the photographic evidence at these sites but have been reported from scats gathered by earlier fieldwork when Makalu-Barun National Park was being created in the mid-1980s. In the Bagare area, Himalayan Black Bear and Himalayan Red Panda habitat overlap in the region. Record of Spotted Linsang from the Kali Khola is the 2nd photographic evidence for Nepal. Yadav et al. 2018 reported the first photographic evidence of the species from Annapurna Conservation Area since the nineteenth century. The species is new for Makalu-Barun National Park or could be first photographic evidence from the park.

Ten species of bird species (Blood Pheasant, Himalayan Monal, Small Niltava, Yellow-billed Blue Magpie, Plain Thrush, White-browed Fulvetta, Black-faced Laughingthrush, Blue Whistling Thrush, and Hill Partridge) were captured in the camera trapping data.

3.2 Summary of Key Wildlife Photo Findings

- Altogether 3,741 records (957 photos of animals) were obtained from six locations in the Barun Valley in MBNP, including 1095 nighttime photographs.
- 18 mammalian species were recorded
    - One globally Endangered species, two Vulnerable species and three Near Threatened species has been recorded

- Nationally, three species were Endangered, three species were Vulnerable, two species were Near Threatened while three species were data deficient species.
- Spotted Linsang were first recorded observation in Makalu-Barun National Park while two localities of Red Panda has been explored.

- Tenavian species were detected.
    - Large sized birds like national bird Himalayan Monal and Blood Pheasant were descending down to lower elevation during the heavy snowfall in the region.

Due to unique and difficult geographic terrains, Yeti Trail (Barun valley) is a great place to study the movement of mammal's species. Presence of globally threatened species and some rare species add the value in the project sites. Careful study design and long-term monitoring the critical camera traps sites eventually know the consequences of climate change on their species behavior.

Table 8: Species recorded, their global and national status along with number of photos and independent events and their percentage.

Species	Scientific name	Red List		No. of photos	Independent Event	Percent
		Global	National			
Himalayan Goral	*Naemorhedus goral*	NT	NT	339	71	44
Mainland Serow	*Capricornissumatraensis*	VU	DD	273	32	20
Northern Red Muntjac	*Muntiacus vaginalis*	LC	VU	128	13	8
Orange-bellied Himalayan Squirrel	*Dremomyslokriah*	LC	LC	21	7	4
Assam Macaque	*Macaca assamensis*	NT	VU	16	6	4
Nepal Gray Langur	*Semnopithecus schistaceus*	LC	LC	11	4	3
Leopard Cat	*Prionailurus bengalensis*	LC	VU	13	4	3
Himalayan Tahr	*Hemitragusjemlahicus*	NT	NT	13	3	2
Masked Palm Civet	*Pagumalarvata*	LC	LC	8	3	2
Red Fox	*Vulpes vulpes*	LC	DD	11	3	2
Himalayan Red Panda	*Ailurus fulgens*	EN	EN	6	2	1
Royle's Pika	*Ochotona roylei*	LC	DD	4	2	1
Spotted Linsang	*Prionodonpardicolor*	LC	EN	3	1	1
Himalayan Black Bear	*Ursus thibetanus*	VU	EN	4	1	1
Yellow-throated Marten	*Martes flavigula*	LC	LC	2	1	1
ChiropteraSps.				1	1	1
Sciuridae sps.				8	3	2
Murid sps.				5	2	1

4 Bioacoustic Data Analysis Framework

4.1 Framework Overview

Processing of the large amounts of bioacoustic data (see Bioacoustics Data section 2.3.3) is not possible without a computer. The Songs of Adaptation project has developed a framework for understanding these data. The framework includes a number of tools first implemented as part of the Barun Biomeridian Research Project, but now applicable to a wide range of sites and applications around the world.

The first tool is a way to Listen to the audio data without having to download it to a local computer. The second tool is a method for Labeling the data. If an expert listens to the data and recognizes the species, they can label the data with the name of that species. The labeled data are then used to train an Artificial Intelligence (AI) Model which can quickly identify similar audio samples in the large data sets.

These tools build a methodology to make the Big Data of bioacoustics accessible to stakeholders who wish to ask questions of the data. The Songs of Adaptation project seeks partnership with local experts and stakeholders to determine which species to study and what questions are of most importance.

Nepal has been a leader in the testing and implementation of this project. This framework was first tested as part of the Barun Biomeridian Research Project and is now being expanded to data from Madidi National Park in Bolivia and sites in the Potomac River Basin in USA.

4.2 Working with Bioacoustic Data

Bioacoustic data can be listened to or represented visually. This visual representation is called a spectrogram and shows the frequencies represented and the magnitude of at each frequency. See Figures 9 and 12 for sample spectrograms.

For some applications, including much of the bioacoustic data analysis done as part of this project, a Mel spectrogram is used (see Figure 9). Mel spectrograms have a frequency scale based on perceived relative pitch that matches the relative pitches heard by the human ear.

When considering acoustic data, we often think of listening. But for a computer, image recognition, like Mel spectrograms, is easier. Most bioacoustic AI algorithms, including those used here, are built on image recognition algorithms.

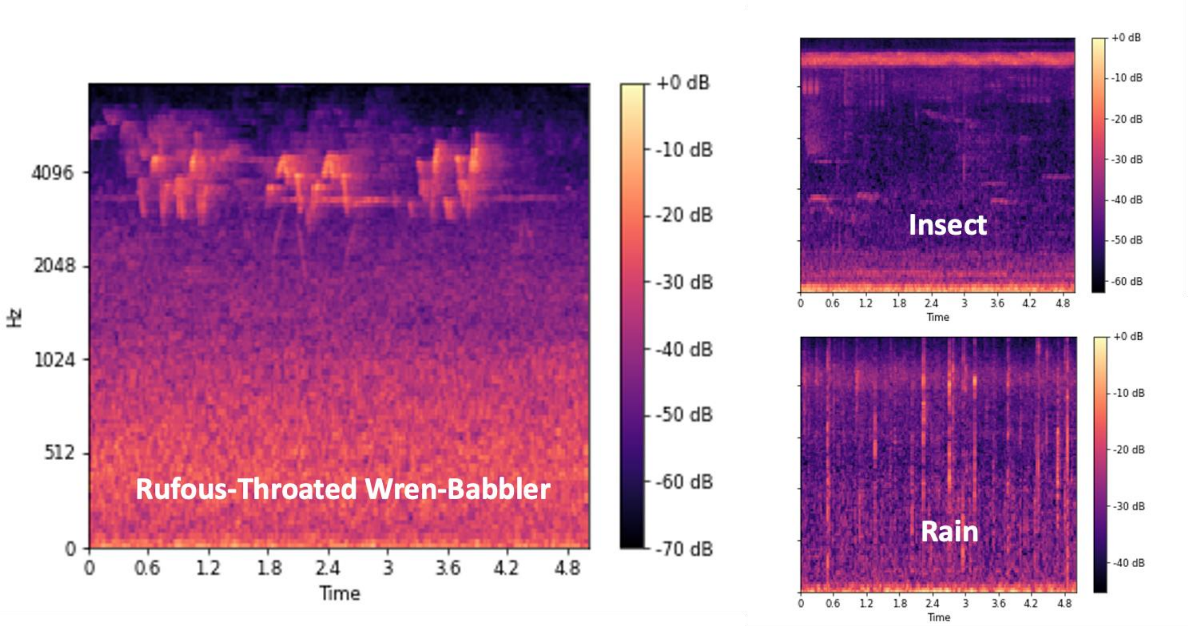

Figure 9:Example Mel spectrograms

Due to the magnitude of data collected in long-term bioacoustic studies, using a single computer to store and analyze the data is not possible. For this reason, the framework built for this project is based on cloud-based data storage and analysis. The two major components are as follows:

1. EarthHz, a website for collaborative online data listening, labeling, and analysis for the model. See EarthHz here: https://data.songsofadaptation.org/
2. EarthHz Neural Network model for communities to learn, train the model and get results for informed adaptation in a changing world.

These tools are described in greater detail in Sections 5.3-5.4 of the report, and data analysis examples for the Barun Biomeridian are presented in Section 6. The process of using these tools includes the following steps:

1. **Collect** sounds from nature and **Listen** to them
2. **Label** the sounds and **Train** the model to recognize the sounds
3. **Run** the model and **Verify** whether it correctly identified the sounds

These steps are done in collaboration with local communities, local field assistants, and local experts. Results represent local efforts to understand local ecosystems and local changes - combined with the power of Big Data, Cloud Computing, and Artificial Intelligence.

As shown in Figure 1, this project observes ecosystem data and uses cloud-based data storage and analysis to convert these data to usable information. This information is distributed to stakeholders locally and globally to assist in evidence-based decision making. The human energy of stakeholders goes into adaptation and management, which affect the environment and contributes to ecosystem change.

4.3 EarthHz Website

The field team collects the audio data from remote stations and stores that data on duplicate hard drives. A copy of these data are uploaded to Microsoft Azure Data Lake cloud-based storage. These data can then be accessed for listening and labeling through the EarthHz website.

The EarthHz website enables collaborative labeling, verifying, and model sharing with global, cloud-based, mobile-friendly access to stream audio, label, and view model results. Written in Flask, EarthHz is a gathering space where multiple open-source models can be uploaded and retrained with more accurate labels.

Data streams from Azure without requiring users to download or maintain their own copy of audio data. Through research and iteration, this project will work towards the most efficient process for returning information and insights to communities to empower local conservation action to protect remote biodiversity hotspots in a swiftly changing climate.

EarthHz is a flexible website where experts can label audio data manually, or use audio clips already on xeno-canto (a library of bird sounds) or other external already labeled species calls. Clusters of similar calls can also be uploaded for efficient labeling. Initial training data for the model can be created by clustering similar sounds using Kaleidoscope software on a local computer. The cluster csv file uploaded onto EarthHz streams 4-second clips and displays the spectrogram. These tools help make the most efficient labeling with the least amount of time for experts and the most use of machine learning.

The project team all works together on EarthHz website and invites more experts to listen. Machine learning is only as good as the data with which it is trained. This project relies on data collaboratively labeled by experts across the globe.Detailed training materials for EarthHz can be found in Annex 1.

4.4 Artificial Intelligence Model

This project designed a framework to analyze species presence in large amounts of recorded audio data. It includes the steps to: collect audio data from the field, listen and cluster for species, label and train species calls, run the artificial intelligence model on years of audio and verify results to use for species presence research papers and conservation action.

Once species information is labeled in the bioacoustic data, this information can be used to train an AI model. Leveraging Microsoft and the open-source software community's best technology, this project coded the EarthHz Neural Network model with TensorFlow (an open source machine learning library widely used for image recognition) and open source Panotti components in the model. The model can learn the spectrogram of any objects such as species, wind, rainfall, etc. Spectrogram differs from species to species as differing their calls and songs.

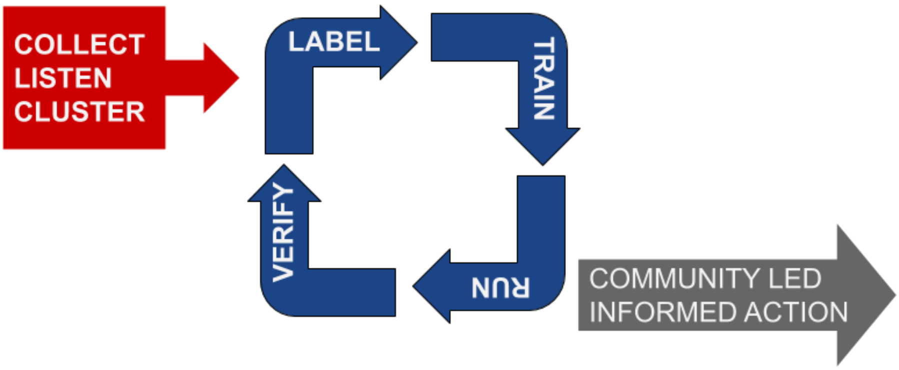

Figure 10: Framework to analyze species presence in large amounts of audio data.

Through EarthHz, researchers and colleagues work together to label bird calls they hear, through online collaboration. Several hundred recordings of the same labeled sound/call are needed to train the computer for which participation of a larger number of personnel (natural resource managers, conservationist, academicians, researchers, interested community persons etc.) would play significant roles even for substantial use of the primary data.

The team trains the model using the EarthHz website. The AI model learns to recognize and find the bird calls in all the data. The model can test it's own accuracy and improve before it is run on all the audio data. The multi-channel neural network audio classifier preprocessing within the model standardizes the size and randomly divides into two sets: 80% training data, 20% data saved for verification. The model trains on 80% of the data, then verifies on the 20% of the data. Once trained, the computer can quickly scan large quantities of data to identify those calls. It identifies the probability of occurrence of species in terabytes of data of data collected by this project. Using Microsoft's Databricks cluster computing, the model distributes the data over dozens of virtual machines to process swiftly in the cloud. This allows for faster analysis of the data and returning of results and graphs online for viewing. Output results with time series and species prediction are uploaded to EarthHz for further verification by experts.

The results from running the model have to be assessed and verified to confirm if the AI is correctly identifying the call. If they are verified correct, then the species presence data may be used for research, such as studying the diel activities pattern and seasonal arrival and departure of species in the Barun valley. Ultimately, visualizations will be displayed for community collaboration and insights. If the results are not yet correct, then researchers continue to collaborate to add more training labels and the model is run again. See the diagram showing this framework of collecting data, training, and verifying so information on these species may be used for conservation action.

5 Bioacoustics Data Analysis in the Barun

As shown in Figure 10 above, this project has designed a framework for analyzing bioacoustic data in the Barun to study species presence. This section describes each step, the successes and challenges and preliminary examples:

- collect and listen
- label and train
- run and verify
- visualize

Although the results are not yet research grade, the report below focuses on preliminary examples (such as the Satyr Tragopan *Tragopan satyra* and other example species selected) for the early testing of the model and framework. Much has been learned from the early tests and much work is still needed to make the tools better for action in the communities.

5.1 Collect and Listen

Six bird species thus far have been selected to test the tool. Email songs@future.edu if you have species of interest to add.

- Himalayan Cuckoo: *Cuculus saturates*
- Satyr Tragopan: *Tragopan satyra*
- Great barbet: *Megalaima virens*
- Collared Owlet: *Glaucidium brodiei*
- Rufous-Throated Wren-Babbler: *Spelaeorniscaudatus*
- Yellow vented warbler: *Phylloscopuscantator*

As an example, Figure 11 shows a spectrogram of Satyr Tragopan (one of the selected bird species) where the species' gives repeated deep, wailing drawn-out call wah, waah! Oo-ah! Oo-aaaa! Raising in volume and becomes more protracted until it becomes almost a shriek; also a wah, wah uttered at any time of the day. This call is represented by a spectrum of repeated deep wailing drawn out call Wah short notes right around the 406 Hz frequency to 2437 Hz.

Successes

- Team members in Nepal are learning to directly upload audio data to online Azure cloud storage during COVID times when sending data is difficult.
- The data are backed up and secure and available for in-country access.
- Researchers with an access account can stream these data from anywhere in the world on their computer or smartphone.

Challenges

- Transfer of data from memory cards to hard drives to the cloud is challenging in rough field conditions. This process is even more challenging during COVID with travel restrictions.

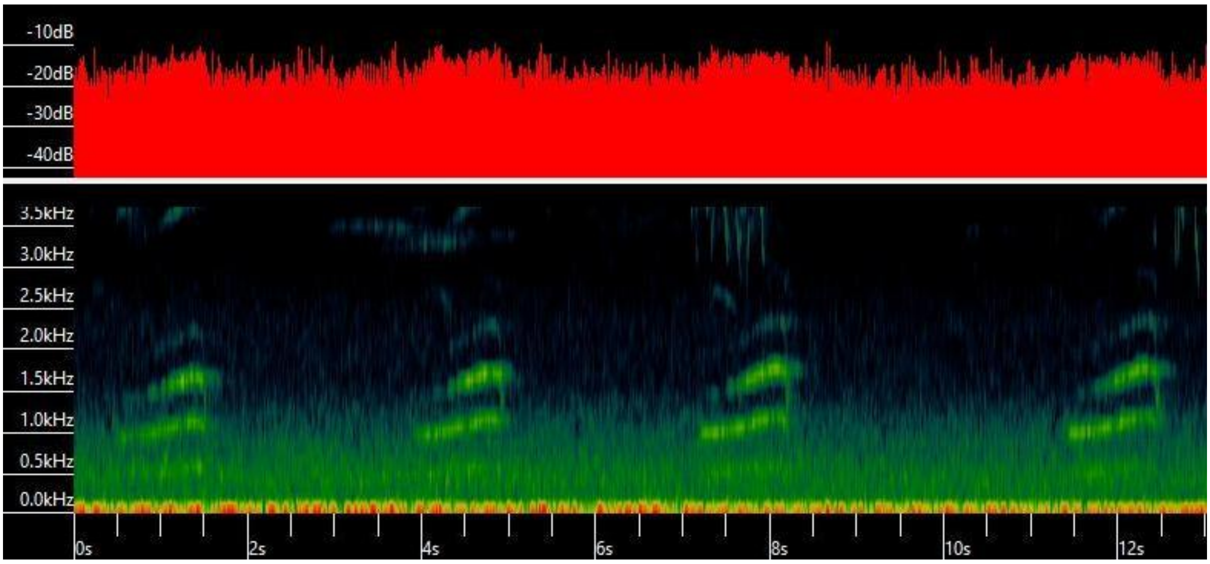

Figure 11: A spectrogram of Satyr tragopan showing deep wailing drawn out call Wah short notes right around the 406 Hz frequency to 2437 Hz.

This project has begun by choosing rare or threatened species, as long as it is not a hard call for the machine learning model to learn. Here is an example of why one species was chosen:

Satyr Tragopan

Scientific Name: *Tragopan Satyra*
Nepali Name: Munal
IUCN Status: Near Threatened
National Status: Vulnerable
Protected Species
Population Trend: Decreasing
National Population Estimation: <1000
Habitat: Moist, temperate broadleaved and rhododendron forest with dense undergrowth including bamboo
Elevation Range: 2,590-3,800 m

Figure 12: Tragopan Satyra (Photo by: Rejaul Karim)

5.2 Label and Train the AI

Manual Identification of Satyr Tragopan *Tragopan satyra*. Based on the habitat and elevation as well as temporal calling pattern of the species, cluster analysis was done using the Kaleidoscope software. Based on the cluster analysis, manual identification was done to each identified call of Tragopan. These identified calls were uploaded to the EarthHz and labelling was done. 232 spectrograms were manually labeled to represent the Call and song of Satyr Tragopan *Tragopan satyra*.

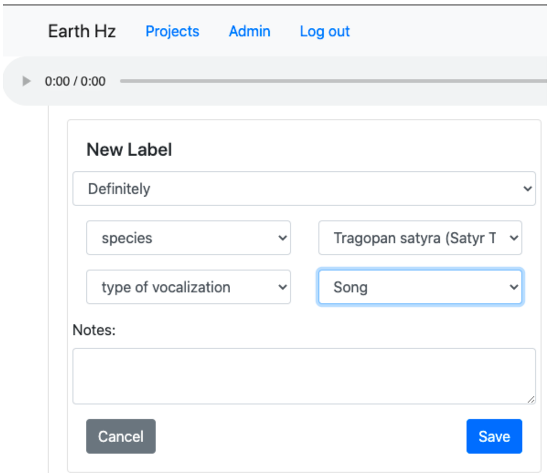

Figure 13: Labeling interface on EarthHz

1,551 total labels for 6 bird species of interest (Table 9) have been added collaboratively through the online tool EarthHz for training:

Table 9: Number of labeled samples for each species

Himalayan Cuckoo *Cuculussaturates* 141 labels	Satyr Tragopan *Tragopan satyra* 232 labels	Great Barbet *Megalaima virens* 368 labels	Collared Owlet *Glaucidium brodiei* 481 labels
Rufous-throated Wren-babbler *Spelaeorniscaudatus* 222 labels	Yellow-vented warbler *Phylloscopuscantator* 107 labels	Background and environmental sounds Negative training data for the model 1,000+ additional labels	

Successes

- A dozen Nepali users have joined to listen online. (And over four dozen users globally on EarthHz.) Some have labelled and shared the project with their colleagues.
- The Nepali team are administrators of the website and are increasingly managing the project in-country.
- The online framework is flexible. Researchers interested in a deeper analysis can label in bulk. Software called Kaleidoscope clusters similar audio and researchers can upload large amounts of bird calls in bulk.

Challenges

- Training the AI takes time. The AI needs a person to label at least 200-300 of the same bird call in order for it to learn the bird species.
- More complex bird calls need more labels, i.e.: 500+. It is hard for the AI to distinguish between close calls of species that sound similar.

In summary, the developed AI model was designed to be applicable for all the project's sites of the Future Generations University such as Makalu-Barun National Park in Nepal, Madidi National Park in Bolivia and Chesapeake Bay Watershed in USA. Any interested person can get into Earth Hz and learn more through www.future.edu or www.songsofadapation.org. In each site, the model prompts the participants to choose station, date and time of their interest and accordingly plays the audio of selected options where the sound of the species of interest is selected and labeled (Figure 3).

5.3 Run and Verify Results

Satyr Tragopan *Tragopan satyra* results are not yet accurate to be used for research. They will be again verified manually then second stage re-modelling to get the final outputs.

Satyr Tragopan *Tragopan satyra* at Ramite station(Figure 14)
See results here on EarthHz

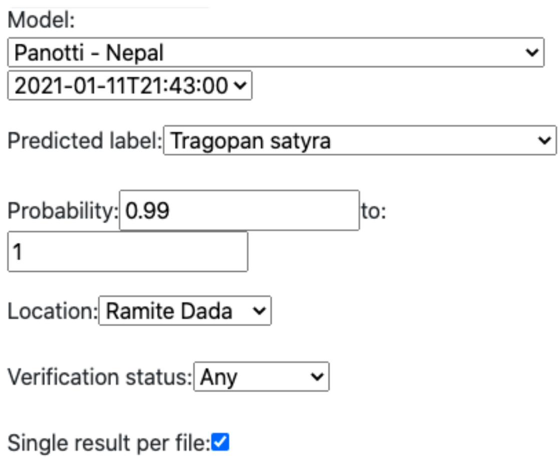

Figure 14: Interface to Results of Tragopan satyra at Ramite Station on EarthHz

5.4 AI Model Results

Based on the final outputs of Satyr Tragopan, following results were drawn:

A total of 523 advertisement calls of Satyr Tragopan were recorded only from Ramite Station. Among this, 213 calls were recorded in 2018 while 310 calls were recorded in 2019. Based on our recording tragopan gives the first call on 15 March whereas the last call was recorded on 16 May accounting a total of 61 days to attract females for courtship or defend its territory. Tragopan was mostly vocal during the fourth Week of March to the first week of May, peaking during the third week of April. Based on this for Tragopan, this period is suitable for dawn call count survey and best at the 3rd week of April (Figure 15).

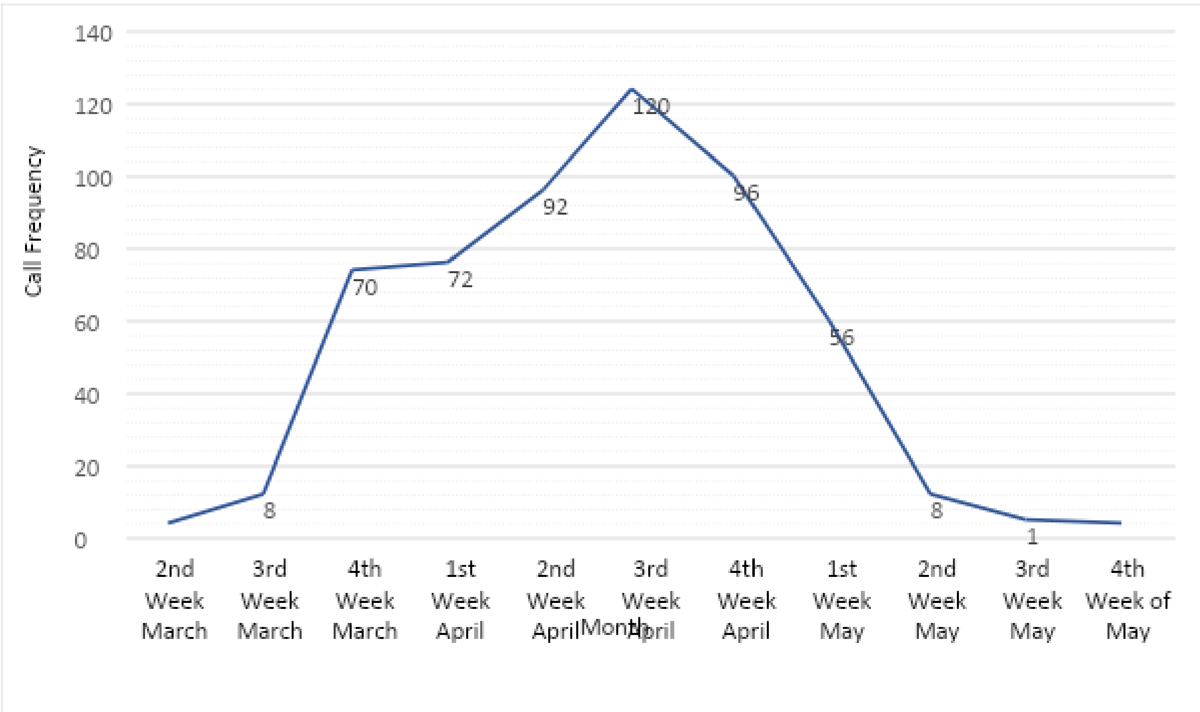

Figure 15: Frequency of advertisement call by Satyr Tragopan in the Ramite station during breeding in Barun Valley.

Daily Vocal pattern of Satyr Tragopan

The tragopan started calling in the dawn from 04:44 hrs and the last call was heard at 18:44 hrs. The frequency of call peaks just before the sunrise and sharply declines after the sunrise. Additionally, the dusk call started from 17:35 hrs and peaked just after the sunset, sharply declining then (Figure 16). However, the frequency of dawn call was more than the dusk call, signifying dawn call count survey, around 45 minutes earlier than the sunrise is the best time for the survey of the Satyr Tragopan.

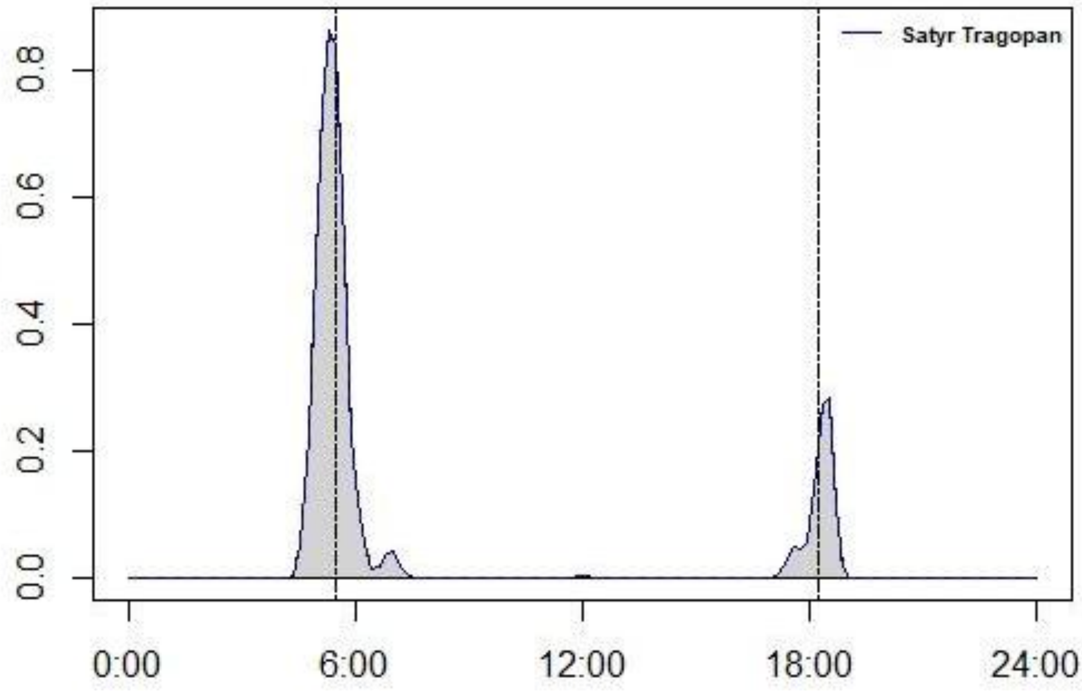

Figure 16: Daily vocal pattern of Satyr Tragopan in the Ramite Danda, MBNP.

Successes

- The AI is recognizing some species and returning thousands of clips of bird calls that can be labeled correctly (e.g., Figure 17).

Challenges

- The AI is about 50% accurate and recognizing correctly some species of interest. For example, see the Satyr Tragopan (Figure 17).
- However, the AI is still confusing Satyr Tragopan with rooster and other sounds (see Figure 18).
- A process is needed for verifying when results are research grade for publishing AI results species presence data.

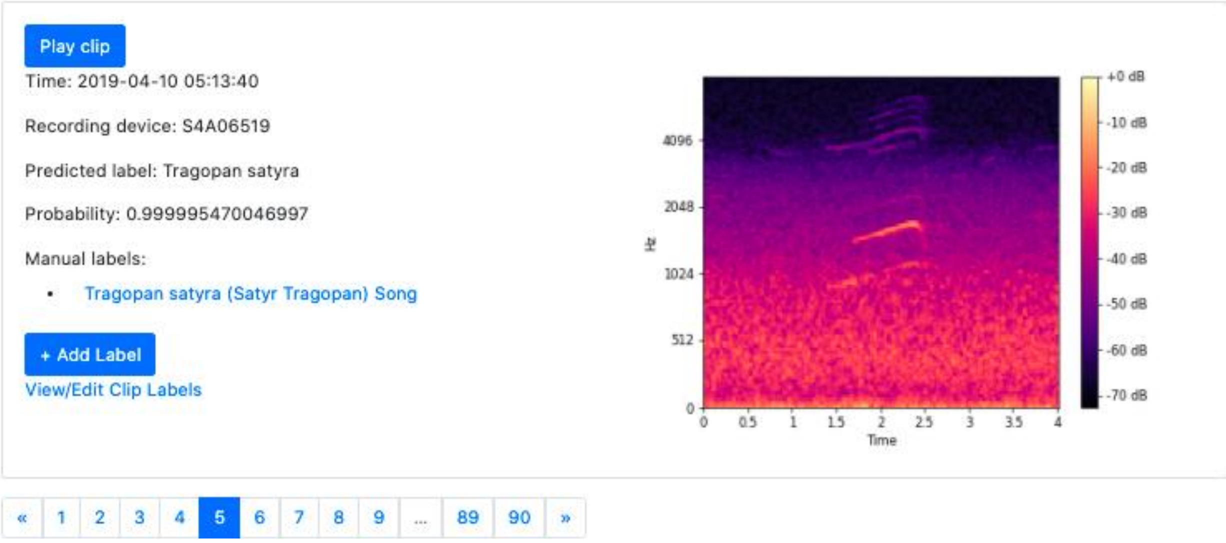

Figure 17: Spectrogram Satyr Tragopan identified by the AI model

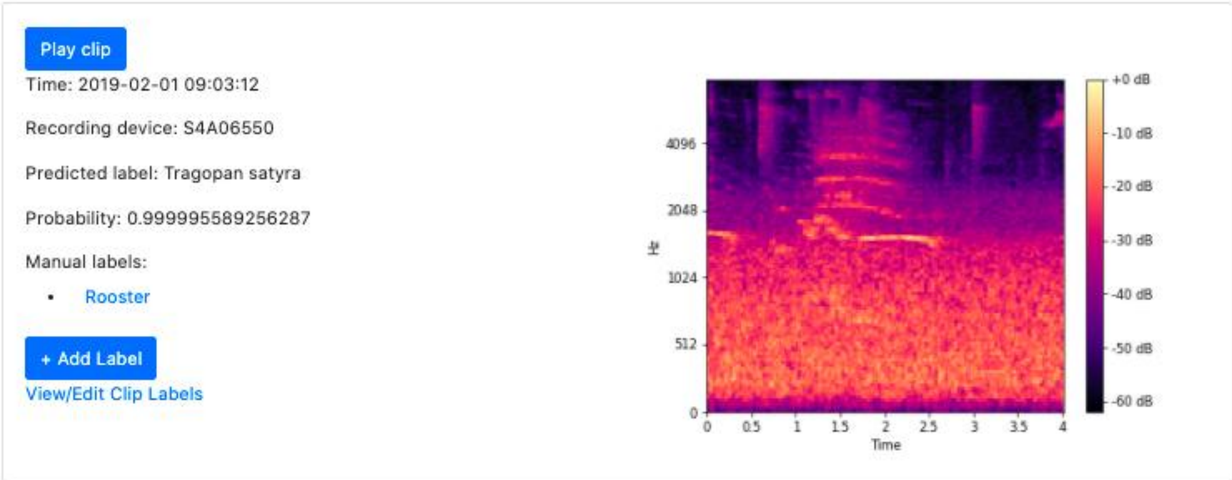

Figure 18: Spectrogram of rooster confused with Satyr Tragopan by the AI model

As seen in Table 10 below, this project has run the model three times and will soon run the model a fourth time with new labels and training data for the species mentioned above.

More labels mean more accurate results. This research is ongoing. Iteration and continued work and learning is key to getting research grade results from the AI model. Community teamwork on labeling and field surveys to learn more about the species all work in partnership with the AI model for success.

Table 10: AI model iterations

Model iteration	Species Analyzed (# positive labels: # results*)	% Verified	# of Labels	# of Results
(sorted by: most recent)	*.99-1 threshold probability, one result per file, green if verified 75%			
Nepal Model January 2021	Himalayan Cuckoo *Cuculussaturatus*	needs more labels	141	1330
	Satyr Tragopan *Tragopan satyra*	needs more labels	232	890
	Great barbet *Megalaima virens*	needs more labels	368	3620
	Psittaculakrameri (trained with external labels)	presence unknown	788	none
	Collared Owlet *Glaucidium brodiei*	needs more labels	481	5540
Nepal Model July 2020 (preliminary running in April 2020)	Rufous-Throated Wren-Babbler *Spelaeorniscaudatus*	needs more labels	220	9520
	Yellow vented warbler *Phylloscopuscantator*	needs more labels	93	3850

5.5 Comparison with Field Survey

A total of 161 bird species were recorded during a 13-day survey in the MBNP in November 2019. Yeti Trail (Barun Dovan-Yak Kharka) recorded 139 bird species, while Jante Odar to Seduwa recorded 22 more (Makalu trekking route). A total of 1800 bird individuals were recorded in the entire survey. Similarly, 54 species of birds were identified by bioacoustics songs recorded in different stations in the study area and 10 species of birds were captured in the camera trap survey. Altogether, 186 bird species belonging to eight orders and 43 families have been identified for the study area by compiling three survey techniques. The survey found three globally Near-Threatened species, as well as two critically endangered species (White-browed Piculet *Sasiaochracea and* Rufous-throated Wren-babbler *Spelaeorniscaudatus)* two Endangered species (Broad-billed Warbler *Tickelliahodgsoni and* Yellow-vented Warbler *Phylloscopuscantator*), and six vulnerable species and two Near Threatened species nationally across the Study area (Annex 4).

Among all the species, six species were selected for the in-depth survey using the bioacoustics tools. These are Satyr Tragopan, Himalayan Cuckoo, Rufous-throated Wren-babbler, Great Barbet, Yellow-vented Warbler, Collared Owlet. The species were chosen based on their global status as well as simple vocal behaviors that are easier to train in machine learning. Species like Satyr Tragopan is habitat specific game bird threatened by anthropogenic stresses. Breeding season for the species lasts from the third week of March to the second week of May. The breeding of tragopan may be triggered by an increase in temperature and precipitation in the spring. In the future, an increase in temperature before the actual breeding time may have an impact on the species' breeding behavior. Monitoring the species and the temperature in the area could help us figure out how the Satyr Tragopan and other indicator species become vulnerable as the region's temperature rises in future.

6 Community Centered Works

The Makalu-Barun National Park Buffer Zone includes the local communities Simbung, Syaksila, Lingam, and Mangkhim villages of Ward 4 of Bhot Khola Rural Municipality: 1,172 individuals (584 male and 588 female) belonging to 235 households.

We believe that research and development projects are incomplete without community engagement, participation and play a role as an agent of the development. Community is the co-equal investors, implementers, and users of the success. The success depends upon the stakeholders and experts/scientist's integration, a collaboration working as a three-way partnership. Community-based success leads all three sections such as research, learning, and action.

The project can complete the successful research and community development projects only with proactive community participation to get reliable data, the right information, measurable evidence, and sustainable adaptation by the community. So, we trained local youths and they are collecting Data, repairing devices, and communicating to partners. These Youth can be the successor of the project for the sustainable leaders to continue BBRP in cooperation with MBNP and local government.

Effective community engagement in the project, awareness, empowerment, and skill education is the priority to the success of research and uplift their economy, to improve health status and environment.

Therefore, the project focused on leadership and human energy development such as trained a number of youths on community development management, community forest user group on Seed-Scale and climate change, and a formed local coordinating committee representing forest user group and Various income generation groups within each village. This committee and groups play a great role in the BBR project and improve their economic, health and environmental conservation. Leadership and empowerment training for stakeholders and communities increased the skills and knowledge for communities and individuals' adaptation to develop and implement sustainable development in the context of climate and anthropogenic change.

To reach these goals, the following activities were conducted as part of the Barun Biomeridian Research Project. The COVID-19 Pandemic of 2020-2021 halted most community centered activities, but this remains an important part of the project as it moves forward.

6.1 Formation of Project Taskforce and Coordination Committee

A Taskforce for the project has been formed under the chairmanship of Chief Warden of the MBNP, combining Assistant Wardens and Rangers of MBNP itself and the representatives from TEF, FGU, Arun-Barun/Hatiya Buffer Zone Committee. This taskforce is for partnering and monitoring the project activities.

6.2 Local Coordination Committee

A Local Coordination Committee was formed in Bhot Khola Rural Municipality-4 during the project's preliminary study period in 2018 in order to involve their active participation in the project. This has been reformed on May 23, 2019. It comprises a total of nine persons: one chairperson, one secretary, one treasurer and six members. The committee is represented from local village forest groups and its leaders (i.e.,Arun-Barun/Hatiya Buffer Zone Forest Committee, Lumba-Tembang Buffer Zone Forest User Group, Tutin Buffer Zone Forest User Group and Thulo Chandane Buffer Zone Forest User Group).

6.3 SEED-SCALE Training

A SEED-SCALE (Self-Evaluation for Effective Decision-making - Systems for Communities to Adapt Learning and Expand) training was held in Khandbari, Sankhuwasabha for three consecutive days in 2019 to encourage and empower the participants for creating three-way partnership, their ownership and engagement in the Project, and applied community change and sustainable development through learning and applying the SEED-SCALE concept. A total of 18 persons (nine Female and nine Male) from Local Coordination Committee, TEF and different Community Forest Groups had participated in the programme.

The training has been successful to achieve a number of outcomes:

- The participants were really encouraged, enjoyed and developed a practice to learn, share, work and grow together in the team.
- They were able to define their own community with conceptual clarity through assessment about strengths, weaknesses, opportunities, and threats of their respective communities.

- They were able to learn, understand and internalize the concept, approach, and process of SEED-SCALE by adopting and applying its several steps such as four basic principles, seven tasks to sustain momentum, five criteria to assess progress, and three dimensions of scalability for their community empowerment and transformation.

Figure 19: SEED-SCALE training in Khandbari, 2019

They have developed a plan of action to promote, expand and scaling-up of SEED-SCALE concept for their community empowerment, social change, and transformation (for detail see Project's achievement report April 2019-September 2019 – Annex 2).

6.4 Climate Change Awareness Raising Training

Climate change awareness raising training was conducted in Khandbari for three consecutive days in 2019 to introduce climate change and its impacts, and to prepare a climate resiliency plan using LAPA (Local Adaptation Plan of Action) method. The training was accomplished under three stages:

1. talking on climate change and its impacts and noting down the climate change impacts of past 30 years based on their knowledge,
2. drawing local maps to identify the key climate prone areas and reasons how climate change can affect these areas, and
4. developing key climate change adaptation and mitigation plan (for detail see Project's achievement report April 2019 - September 2019 – Annex 2).

Figure 20: Participants in climate change training in Khandbari, 2019

6.5 Summary of Community Centered Works

Environment and economy are changing rapidly due to climate change and communities are at the center of many of these changes. These changes affect people's lives, they have to face the negative impact of climate change while they act as the users and guardians of nature and its resources.

After the various training mentioned below and exposure tours, they have now started to realize the changes in climatic patterns and their consequences. In this context, it has been realized a need for science-based education for the communities to cope with the consequences of climate change. So, the project conducted the following leadership, awareness, and empowerment training:

1. Community Development Management (CDM) training for 11 youth man/women volunteers,
2. Training cum exposure tour for 10 community leaders, and
3. SEED-SCALE, Climate change training for 18 members of Buffer Zone Forest User Groups, Local Coordination Committee members, Buffer Zone Forest Committee member, MBNP staff, and TEF staff.

After the above training, participants applied to learn from training and started the following activities:

a. Formed various groups such as women groups, farmers groups, Youth groups, Social welfare committees, and strengthened community forest, user groups.

b. Group started sanitation around the villages,
c. Every group collected funds for income generations and social projects.
d. Participants supporting and teaching in school
e. Started Homestay and shops by participants after the training.
f. Built Toilets with every house help from the local government and mentoring by volunteers.
g. Starting kitchen gardens and horticulture.
h. Cardamom production crosses the Barun Valley.

Barun Valley has great changes on its horizon as a new crop of highly trained community development volunteers to grow with the help of the Local government, Makalu National Park officials, TEF, FGU, and Share & Care Nepal. Barun Bachaon Taskforce (BBTF)has been growing local capacity for change in vulnerable communities providing management, leadership and technical skill training across Barun Valley.

We had a discussion and short interview during the community survey, meeting, and training. According to the communities and participants "the CDM course and exposure visit cum training was great potential in the context of Nepal's isolation to serve as a forum for community-based learning." Their applied work makes it "possible to extend learning opportunities directly to the village level" by working with CDM graduates and community volunteers.

During our BBRP field visit, we had interaction with participants and communities. They shared their learning, using the material and techniques they learned from the training exposure visit. It was a significant success through a variety of activities mentioned above in social-ecology and socio-economic such as livelihood projects, learning and applied Sanitation and hygiene education, women's empowerment, environment conservation, protection, and proper utilization of the local resources>eco-friendly agro-forest, herbal medicine, child education, and income generation project.

Started home Stay and shops by the participants as an example and demonstration for other communities that they can learn from them. (Dukpa's homestay in Syaksila, Rabina's homestay and shop in Gola and Chukchet's shop in Barun Dovan). We spent a few overnight these homestays. It was well managed with Toilets, a clean room, and local food. Dukpa becomes key social workers and leadership across Barun areas and the key person monitoring Barun Research Project devices and community engagement of livelihood project. Three women participants we meet (Yangmu from Syaksila, Labina Rai from Lingam and Chukchet from Barun Dovan) doing wonderful work helping the community, forming women groups, and teaching in school (Labina in Lingam and Yangmu in Syaksila). Her group member tells the story about how she changed her behaviors and started help the women group. After the CDM training, First, she starts keeping clean her house, herself clean, dressing and building a Toilet. After that she started sharing how she learned and formed a women's group to clean village around, collect some funds for their group income generation and other purposes. She teaches school children about simple sanitation such as hand washing, use Toilets, Tooth brushing, and face washing before school and from school etc. Schoolchildren started doing what she teaches and what they learned, parents started following their children. Communities inspired by her doing small activities in the school and with women groups. Now she becomes a women leader in Syaksila. Before she joined the CDM course, she was the opposite of present behavior that village people don't think she would be changed such a way, even in a family.

The most important is that she is leading the women groups, villagers and teaching school giving priority to prepare children for school which is the most important stage of children's education. Her group is the most active group among the other groups in their village due to frequent meetings and mentoring. Dukpa is helping her with management, action planning, and social activities. The group is doing various activities including social development such as cleaning around the villages and water system sources, making trash boxes along the footpath, raising group funds through income generation activities and preventive health activities.

This success can be an example of empowering many communities, young girls, women, and teaches improvement of the development concept, which will benefit hundreds of young people and communities. These participants (volunteers) facilitating, mentoring, and learning leaders for other parts of Makalu-Barun National Park. We should have the plan to develop more like these people in the next action plan.

Expressed by the villagers> we had no ideas about the climate changes which make a difference on our farming, agriculture, health, livelihoods, and even how and why we work as a group for village development. Even we didn't know about sanitation, nutrition, health care, income generations, and how to prepare an action plan for the future. A ray of hope came when our youth and women came back from their training and started talking about action plans, climate change, and income generations projects utilizing local resources. Afterward, when the group started work in the village, our lives gradually changed women in particular. For example, we trained more than 39 Youth men and women on community development management (CDM) and women who demonstrate after the training sharing their learning, teaching in school, starting homestay, shops, and other income generation activities. Village women groups learning from them and forming more groups working on income generation activities. Youth participants leading village development projects such as small Hydropower project, Trail construction, Drinking project, and collecting research project Data from Devices.

Expressed by the Participants> in the beginning when we attended training, we didn't believe we could do something? After the training, we hope to do something, when we applied *to learn, we* experienced how a community can change its behavior and lives such as sanitation, basic health care which can be practiced at home ourselves, how to form a group, income generation activities, and its importance etc.

Earlier village women only used to work in agriculture fields and we didn't know about health & hygiene, income generation, helping each other, eco-friendly horticulture and alternative livelihood projects. During the exposure visit and CDM training facilitators and NGO staff taught us about all this knowledge of social work & village development by utilizing local resources. Now we are helping women groups, teaching in school, and doing income generation activities. Without income, we can't help others and work as volunteers.

7 Conclusion

Global temperature rising trend has resulted in the decade of 21th century to be the warmest, and consequently its negative impacts upon biodiversity and livelihood have been reported increasing. These are expected to continue in the future. In this context, during the project period, a foundation was laid to collect regularly the ecological, meteorological, bioacoustics and camera trapped data for long run; processing and analyzing of bioacoustics data was computerized by developing AI models; and educating the local communities about the climate change and its impacts upon their livelihoods, and developing mitigating and adapting plans to climate change along with community empowerment, social change, and transformation plans through SEED-SCALE concept was initiated.

The project continues focuses on the successful implementation of the research result and development action by the local community and stakeholders. **The success** of the project is measured by its implementation, adaptation, outcomes, and sustainable indicators of achievement. In order to keep the programs sustainable and successful, the local community participation and collaboration of partnership is essential to continue. Encourage to increase the involvement of local, national, and international organizations.

The bottom-up action plan will be developed with Village groups, committees, Forest User groups, local coordinating committees, and Taskforce focusing on nature-based entrepreneurs rather than top-down.

We envision supporting communities and enabled them to implement and adapt learning, established a mechanism for the sustainable, inclusive community-led success of the development of climate change adaptation.

7.1 Major Achievements

Over the two-year period that from April 2019 to March 2021, the Barun Biomeridian Research Project has achieved the following:

1. Established eight permanent plots along biomeridian from 1200 to 4000 m elevation
2. Collected ecological data of major tree species to set as baseline dataset that accounts for 42 individual species.
3. Installed instrumental devices to record climatic, audio, and photographs data - HOBO MX2301A, Bioacoustics Recorder (SongMeter SM4), Browning Trail Camera

4. Collected 449,187 records of temperature and humidity
5. Collected 3741 camera trap photographs, identifying 18 mammalian and 10 avian species in these data.
6. Conducted a field survey of avian species in the Barun Valley trekking routes and identified 161 species.
7. Identified 54 avian species in the bioacoustic data collected in the Barun Valley
8. Developed first-of-its-kind in world cloud-based framework to store and analyze bioacoustics data
9. Created EarthHz website for global data labeling and collaborative analysis of results (This is the only such public repository for recording sounds of Nature)
10. Total of 1551 bird vocalizations for six species labeled on EarthHz.
11. Preliminary AI models trained for six avian species, and a framework for communities to label and analyze more species. This has potential for global use in learning to listen to Nature
12. Project performance monitoring and evaluation group at local and national level
13. Initiated skill development and awareness raising education
14. Behavior change began due to trainings: women's groups, savings and within-group loans for income generation, education, and health.
15. Gradual changing income generation activities, particularly for women.
16. Community development management (CDM) training led to development of homestays, shops, and other income generation.
17. Youth engagement in projects: small hydropower, trail construction, drinking water, and collecting research project data.

7.2 Next Steps

The impact of the program's scientific research and on quality of life in communities needs time.This project has completed two years, with a focus mainly on science-based research but also a community engagement and training component. Along with continued data collection, storage, and analysis, the following next steps have been identified for the upcoming three years of the project:

- Install bioacoustic monitoring station in bamboo forest and in the Eastern Himalayan Subalpine coniferous forest.
- Upgrade bioacoustic recording equipment to represent the latest technology.
- Adjust camera trap locations to better capture the rich biodiversity of species in the Barun Valley.
- Through the input of local and global experts, increase the number of species identified through bioacoustic analysis, and increase the number of labeled audio samples per species.
- Collect scientific and birder community input on the usability of the EarthHz website and data analysis framework so users can have more autonomy throughout the process.

- Continue to run the AI model with current and new species.
- Expand the use of bioacoustics to include amphibian species if of high interest.
- Scientific community engagement through presentations, publications, and meetings.
- Ongoing community engagement and training in SEED-SCALE methodology and climate change awareness.

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