Radioactive Soundscape Project

Hiroki Kobayashi[1,2(✉)] and Hiromi Kudo[1]

[1] Center of Spatial Information Science, The University of Tokyo, Kashiwa, Chiba 277-8568, Japan
{Kobayashi,kudo3}@csis.u-tokyo.ac.jp
[2] PRESTO, Japan Science and Technology Agency, Kawaguchi, Japan

Abstract. Acoustic ecology data have been used for various types of soundscape investigations. Counting sounds in the soundscape is considered an effective method in ecology studies and offers comparative data for human-caused impacts on the environment. One particularly valuable dataset of broadcasted recordings from the "difficult-to-return zone (exclusion zone)" area, 10 km from the Fukushima Daiichi Nuclear Power Plant was collected by Hill H. Kobayashi and H. Kudo in the Oamaru District (Namie, Fukushima, Japan) in 2016. These audio samples, which have not yet been analyzed (a total of over 700 h in MP3 format), were continuously transmitted in a live stream of sound from an unmanned remote sensing station in the area. In 2016, the first part of that collection of audio sample covering the transmitted sound recording from the station was made available on the project website. The data package described here covers the bioacoustics in the area. We expect these recordings to prove useful for studies on topics, which include radioecology and the emerging dialects for future observations.

Keywords: Acoustic ecology · Radioecology

1 Introduction

According to the Chernobyl nuclear disaster report of the International Atomic Energy Agency [1], it is academically and socially important to conduct ecological studies concerning the levels and effects of radiation exposure on wild animal populations over several generations. Although many studies and investigation were conducted around the Chernobyl nuclear power plant, there were little audio samples. At last, twenty years after the Chernobyl disaster, Peter Cusack made recordings in the exclusion zone in Ukraine [2]. To understand the effects of the nuclear accident, long-term and wide-range monitoring of the effects of nuclear radiation on animals is required because there is little evidence of the direct effects of radioactivity on the wildlife in Fukushima [3]. Immediately following the Fukushima Daiichi Nuclear Power Plant disaster, whose remnants are shown in Fig. 1, Ishida (a research collaborator at the University of Tokyo) started conducting regular ecological studies of wild animals in the northern Abukuma Mountains near the Fukushima Daiichi Nuclear Power Plant, where high levels of radiation were detected. Ishida reported that it is essential to place automatic recording devices (e.g., portable digital recorders) at over 500 locations to collect and analyze the vocalizations of target wild animals [3]. For monitoring such species, counting the

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recorded calls of animals is considered an effective method because acoustic communication is used by various animals, including mammals, birds, amphibians, fish, and insects [4, 5]. In addition to using visual counts, this method, in particular, is commonly used to investigate the habitat of birds and amphibians [6]. Furthermore, the ecological studies of the environment near urban areas are being conducted using cell phones [7]. However, it is difficult to use such information devices in the exclusion zone as these areas do not have infrastructure services. Therefore, it is necessary to develop a monitoring system capable of operating over multiple years to ensure long-term stability under unmanned operating conditions.

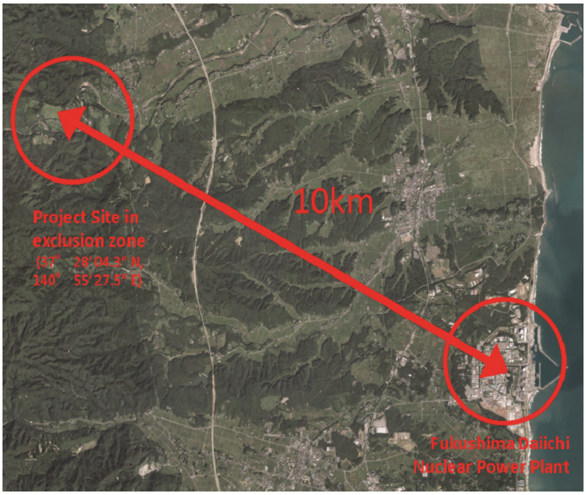

Fig. 1. Location of project site in exclusion zone (37° 28′ 04.3″ N, 140° 55′ 27.5″ E), which is 10 km from Fukushima Daiichi Nuclear Power Plant.

2 Background

As introduced above, in ecological studies, it is desirable to develop a technology that most effectively supports a study with minimal resources. More specifically, we aim to establish a long-term continuously operating ubiquitous system that delivers, in real time, environmental information, such as sound. Researchers worldwide are conducting ecological studies by recording and analyzing the spatial information of wild animal vocalizations [3]. To record vocalizations of wild animals whose behaviors are difficult to predict, it is necessary to continuously operate a monitoring system. As it is difficult to conduct system maintenance due to the severe environmental conditions of wild animal habitats (e.g., when out of infrastructure service areas and in radioactive environments), system redundancy becomes crucial.

We have previously researched and developed proprietary systems that deliver and record remote environmental sounds in real time for ecology studies [8]. Since 1996, this system has been almost continuously operational at the Iriomote Island (Okinawa).

To date, the basic research at the Iriomote Island has expanded to include 18 domestic and international sites, including Los Angeles and the San Francisco Bay area in the United States, Sanshiro Pond at the Hongo Campus of the University of Tokyo in Japan, Kyoto Shokokuji Mizuharu in Suikinkutsu, Mumbai in India, and the Syowa Station in Antarctica (under construction). We have worked with project collaborators and introduced our system to the University of Tokyo Chichibu Forest, Otsuchi in Iwate, Shinshu University, the University of Tokyo Fuji Forests, the University of Tokyo Hokkaido Forest (under construction), the University of Tokyo International Coastal Research Center, and at an uninhabited island in Iwate [10]. We have also demonstrated [10] that (a) the transmission of live sound from a remote woodland can be effectively used by researchers to monitor birds in a remote location, (b) the simultaneous involvement of several participants via Internet Relay Chat to listen to live sound transmissions can enhance the accuracy of census data collection, and (c) the interactions via Twitter allowed public volunteers (e.g., citizen scientists) to engage with and help the remote monitoring of birds and experience the inaccessible nature using novel technologies.

With these achievements, the Radioactive Soundscape project aims to collect, share, and analyze the soundscape data at over 500 locations in the exclusion zone by performing the following activities: (1) Distributing these sound data in the exclusion zone to the public via the Internet, in order to make the live sounds in the area publicly available for listening in real time and (2) distributing these sound data to the public via the Internet.

3 Methods

This project installed the first transmitter station [9] in the exclusion zone area (10 km from the Fukushima Daiichi Nuclear Power Plant). A map of the exclusion zone in Fukushima (Japan) is shown in Fig. 2. The transmitter station is located at the Oamaru district in the Namie town, Fukushima (37° 28′ 04.3″ N, 140° 55′ 27.5″ E). We chose this site in the exclusion zone because it is one of the most difficult areas for long-term

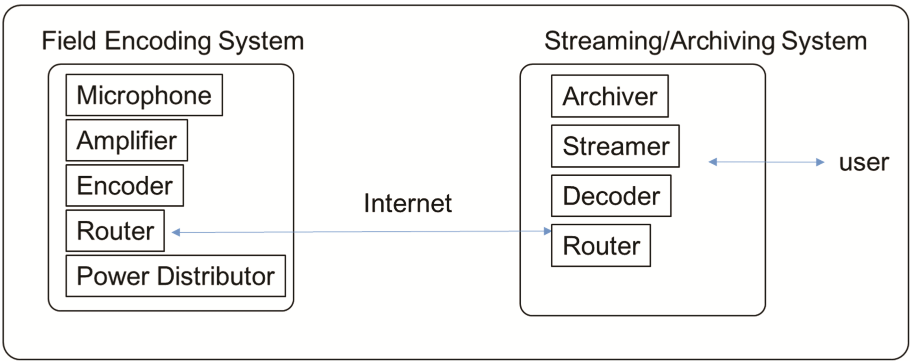

Fig. 2. System diagram of live sound system: field encoding system (left) and streaming/archiving system (right).

and continuous investigations. First, the difficult-to-return zone is the most radioactively polluted zone in Fukushima. Second, no remote sensing method at the surface level is available due to the lack of power and information infrastructure. Third, field surveys are required; however, the amount of workable hours is extremely limited due to radiation exposure concerns. Further, frequently used portable recorders require regular replacement owing to the memory and battery capacities, which is impractical for long-term and continuous investigations.

This project aims to collect, share, and analyze the soundscape data at over 500 locations in the exclusion zone. Therefore, for the first location, we developed a "Live Sound System" and a "Streaming/Archiving System" that enables us to perform the following activities: (1) Distribute the sound data in the exclusion zone to the public via the Internet in order to make the live sounds in the difficult-to-return zone publicly available for listening in real time and (2) distribute the sound data to the public via the Internet. The Live Sound System, as illustrated in Fig. 3, comprises separate subsystems: a "Field Encoding System" (to digitize the live sounds in the forests) and a "Streaming/Archiving System" (to conduct live sound delivery via the Internet and archive the sound data in a recorded file). The technical operational testing notes of the Live Sound System can be found in our previous study [10].

Fig. 3. The first transmitter station at project site in exclusion zone.

The Field Encoding System (Fig. 2) established in the remote forest includes the antenna depicted in our previous study [10]. This system comprises two blocks: an audio block and a transmission block. The microphones (omnidirectional SONY F-115B microphones) are individually connected to the amplifier (XENYX 802, Behringer) of the audio block and their outputs serve as input to the audio encoder (instreamer100, Barix) to convert the microphone sounds into MP3, the format used for subsequent digital sound delivery. As there was no prior Internet connection at the exclusion zone site, we incorporated a satellite Internet service, which was provided by IPSTAR in April 2016. We subscribed to IPSTAR's "Dual" service plan, which provides the largest upload bandwidth of 2 mbps for approximately US $125 per month. There is also a daily limit (2 GB) on data usage per customer. These characteristics of the service plan are important because the research funds required to conduct a long-term ecological study are likely to fluctuate over time. The power supply to the Field Encoding System is provided by a local electric company via a special contract. Indeed, the company needed to reconstruct the infrastructure in the exclusion zone after the devastating damage caused by the earthquake. This reconstruction was important for the long-term continuity of the project. To continuously operate the system using solar panels or other independent power sources, frequent system maintenance at the site would be required.

The Streaming/Archiving System is located in the server room in our laboratory and has a normal bandwidth Internet connection, allowing simultaneous public access to transmissions (Fig. 2). Two servers are used, one for streaming and the other for archiving. The servers were established in the laboratory due to technical difficulties (e.g., the previously mentioned problems with power supply and data download limits) involved in the setup and operation of such a server at the relevant site. The processed audio signal is sent from the microphone, encoded into an MP3 live stream in the Field Encoding System, and transferred to the Streaming/Archiving System. The MP3 live stream can then be simultaneously played on MP3-based audio software worldwide. We use a standard single package of Linux Fedora 14 as the operating system and the Icecast 2 software as the sound delivery server. We have used Icecast 2 in our projects since the beginning and have experienced only minor problems, e.g., a slight delay (0.5 s) in the sound transmission. However, the signal strength of our system is affected by severe weather, such as heavy rain or snowstorms, and this could cause communication delays with the satellite network. To address this, we adjusted the amount of information that could be received by the network (via the Linux TCP Receive Window) to ensure that interruptions do not occur when transmitting sounds on the streaming server. Finally, to share the encoded live sound with listeners at high availability, the archiving server stores all the MP3 sound format files that are sent from the Field Encoding System through the Streaming Server. According to the Radioactive Soundscape project, it was important to make live transmissions publicly available for listening purposes and have access to the archive to experience changes over a day as well as across all the seasons.

This project started with a year of literature search (2011), fundraising with government approval (2012–2014), and the installation of a transmitter station with satellite Internet (2015). Finally, based on official preparations and approvals, a local electric company agreed to sign a service contract with us in 2016 after an intensive feasibility survey of the all transmission facilities at the location. The final construction was completed at the end of March in 2016 in Fig. 3. This project aims to operate the system for 24 h in a day and 365 days a year. Prior to this project, we had experience in operating a similar system for more than 10 years. Therefore, it is possible to operate this project until approximately 2030.

4 Data Records

The Radioactive Soundscape project aims to collect, share, and analyze soundscape data (mp3, 160 kbps, 2ch, mono) at over 500 locations in the exclusion zone. The data records with the organization must meet the following requirements:

1. Identify the project names from the filename
2. Identify more than 500 stations from the filename
3. Identify the event schedule (time) from the filename

For each level, we provide a registry of all the campaigns, stations, and events in universal resource locator (URL) queries. Filenames that indicate the project, station, and start of timestamp are built using a consistent syntax that has the following format:

projectname_station#_date(yyyymmddhhMM).mp3,

e.g., RS_1_201103111426.mp3.

Furthermore, every 24 files (1 day) is archived in a single TAR file.

e.g., RS_1_20160609.tar

The archived sound recordings are stored in the project web site.

5 Technical Validation

We provide a technical validation of the Radioactive Soundscape project data via the Checker file-validation software. Checker 0.96 (http://cgjennings.ca/checker/) performs a technical validation of the received MP3 format data. In addition, it measures the background noise by examining the quietest part of the data. A soundscape is defined as a set of various sounds that are spontaneously generated in a particular environment and that continually change, diurnally and day-to-day over a passage of time. It can be compared to a chorus defined by the geography or other physical aspects and the acoustic properties of an area. From the viewpoint of informatics, the amount and duration of bioacoustic information contained in sounds are small compared with the other continuously present environmental sounds, such as wind and running water. In contrast, the bird and animal calls are only a small fraction of the total soundscape.

Figure 4 shows the measured background noise of the samples (total duration = 742 h) from July 9, 2016 to June 8, 2016 that was validated by the software. The change in the background noise traits, such as the anthropogenic noise and the hum of the electricity power, determine the quality of the long-term structure of the data and the dynamics of the food webs and other ecological networks across the received recording. When the system is continuously operated by recording and broadcasting the sound for 24 h in a day over the entire year, it produces environmental factors (i.e., anthropogenic noise). The quality of the digital signal processed by the real-time audio-processing software decreases as the recording system operates over extended periods. In majority of the cases, the processed signal contains numerous heat-related "hum" sounds. Heat is generated by the recording system itself because it must operate in the extremely high moisture and temperature environment of the site. Therefore, to solve the heat problem, it was essential to set up a continuously operating cooling system. However, it is extremely difficult to configure a hardware mechanism to reliably operate under unmanned conditions.

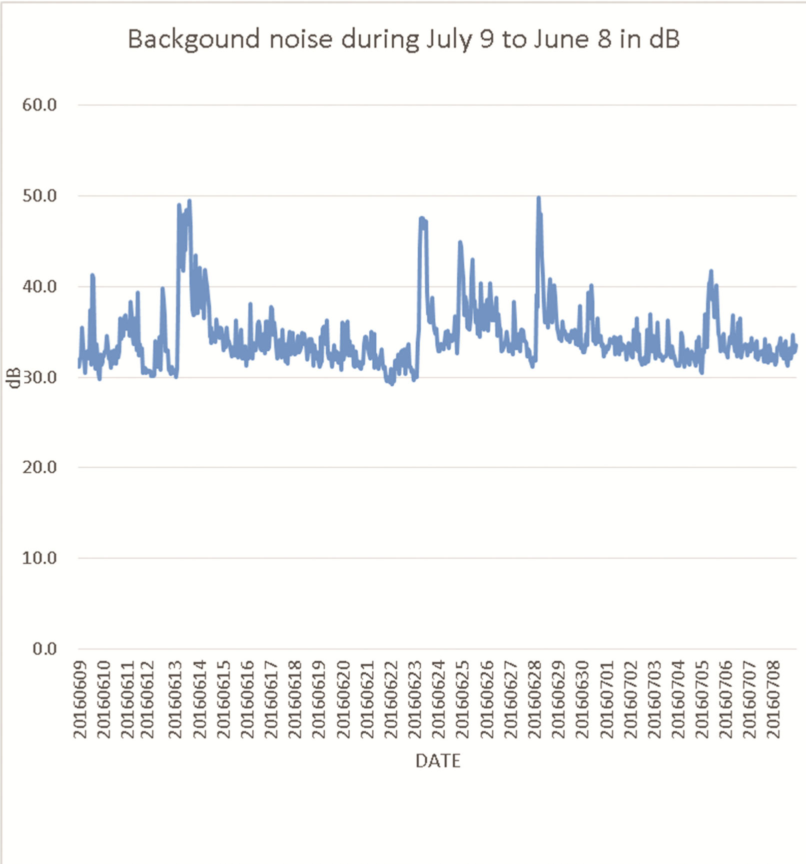

Fig. 4. The measured background noise in dB from July 9, 2016 to June 8, 2016.

6 Discussion

It has been 30 years since the Chernobyl nuclear disaster. In that time, wildlife has returned and appears to be thriving in the surrounding forests [1]. Although 20 million wild animals were killed in the immediate aftermath of the disaster, it is believed that a very small number of wild animals survived and adapted to the changing environment. These animals evolved and prospered in high-radiation areas. However, it took a long time to establish research organizations to conduct ecology studies, and the evolutionary process of the surviving animals remains unknown. Insight into the survival and evolution of radiation-exposed wild animals may result in insights into agriculture and forestry, animal husbandry, and medical care. However, long-term ecological studies of wild animals and their radiation exposure levels are required [3]. During the recovery from the Fukushima Nuclear Power Plant Disaster, the journal Nature (http://www.nature.com/news/2011/110527/full/news.2011.326.html) has pointed out the importance of ecological studies from the very beginning of a disaster. As described introduction, Ishida (research collaborator) of the University of Tokyo, who has conducted ecological studies since immediately after the disaster, has stated that it would be extremely difficult to continue conducting ecological studies on an ongoing basis [3]. However, the domain of human computer interactions can address these issues, and the authors claim with confidence that the proposed project will address these issues successfully through our project web page in Fig. 5.

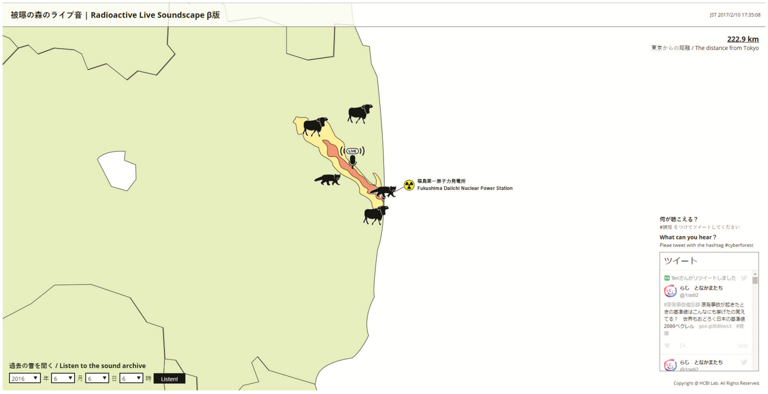

Fig. 5. Web interface for radioactive live soundscape http://radioactivelivesoundscape.net/

7 Future Direction

Investigations into natural environments consider living creatures and their natural environments, and are important to review the value of biological diversity from various perspectives. It is currently possible to obtain ecological information about wild animals in remote areas using various ubiquitous systems. However, an information and electrical power supply infrastructure is essential to the operation of these systems, and thus, they are limited to the areas serviced by such infrastructure studies around the Fukushima Daiichi Nuclear Power Plant. To abate this limitation, researchers have started using wearable sensors for wild animals (Fig. 6). To collect the data recorded by the wearable sensors, it is necessary to recapture the monitoring subjects; thus, wearable sensors are limited to collecting data from the recaptured subjects' habitats. To solve the problems with existing systems, the proposed project will develop "a system where wild animals carry a wearable sensor; record the spatial information in their territory through individual actions; share the information obtained through group actions, with reduced power requirements; and eventually upload the shared information on the Internet.

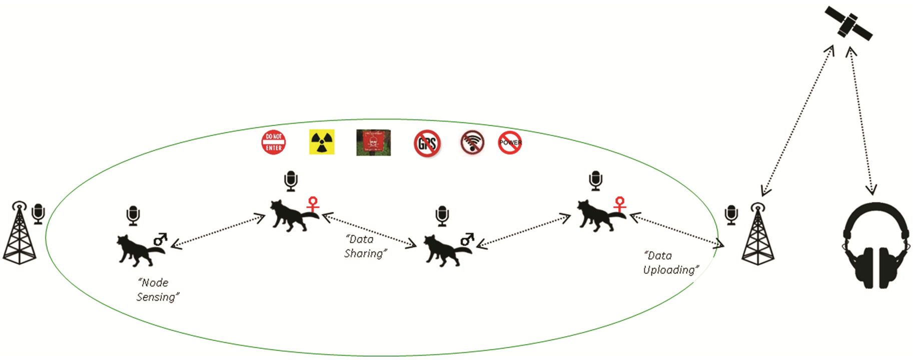

Fig. 6. Proposed sensing system-concept image

8 Conclusion

This paper presents Radioactive Soundscape project for ecology study for the Fukushima Daiichi Nuclear Power Plant disaster. This project aims to collect, share, and analyze sound-scape data at over 500 locations in the exclusion zone. This project also aims to operate the system for 24 h in a day and 365 days a year. The project successfully installed the first transmitter station in the Namie town, Fukushima (37° 28′ 04.3″ N, 140° 55′ 27.5″ E). The final construction was completed at the end of March in 2016. This project aims to operate the system for 24 h in a day and 365 days a year. Prior to this project, we had experience in operating a similar system for more than 10 years. Therefore, it is possible to operate this project until approximately 2030.

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