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# Comprehending Information in Acoustic Signals: A Review of Bioacoustic Studies

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**ABSTRACT**

Development in bioacoustic studies have provided new opportunities to understand the information related with different types of vocalization produced by humans and other living organisms in different conditions. Bioacoustics not only help humans to understand the different types of hidden information present in the acoustic signals of living organisms but also assist in understanding how acoustic signals can be used in improving their health and diagnosing severe diseases easily. Bioacoustics benefit both humans and animals by decoding the relation of the acoustic signals with the behaviour of the animal and environment in which they live. Bioacoustic studies also aid in understanding the effects of anthropogenic activities on acoustic signals of other animals. Monitoring through acoustic tools is most convenient and a large number of precision tools are available in the recent times. This paper reviews the findings of bioacoustic studies published between 2000 to 2020 worldwide. Significant researches in the field of sound communication of different animal species have been cited in this review. Varied animal behaviours can be accounted for based on the sound produced by animals under different physiological state, environmental influences and human activities. Study of animal sounds may be of remarkable value from welfare and conservation perspective.

***Key words :*** *Anthropogenic, Behaviour, Bioacoustics, Conservation, Signals, Vocalization.*

## Introduction

Acoustics is the science concerned with the production, control, transmission, reception and effects of sounds. The word 'acoustic' is derived from the Greek word- *akoustos* which means "heard". Bioacoustics is a branch of acoustics concerned with sounds produced by the living organism or sounds that affect the living organisms. All the living organisms express their emotions using acoustic signals like- pain, happiness, fear and many studies show that we can also use the acoustic signals of the organisms in analyzing the health and welfare of the animals. These acoustic signals also provide us information about the age, sex and body size of the animals (Briefer and McElligott, 2011). Studies have proved that acoustic signals give information of the physical characteristics of the caller (Pfefferle and Fischer, 2006). Humans use both verbal and non-verbal acoustic signals for communication and expressing their emotions while other living organisms use different types of non-verbal acoustic signals for communication and for expressing their emotions. Vocalization is not only important factor in animals but in humans also, because the voice with certain acoustic characteristics is considered attractive (Feinberg *et al.,* 2005). Acoustic signals produced by animals are not just sounds, but an attractive voice can lure the concentration of other members also. It has been observed that in humans, the males having low pitched voice are considered to be more socially and physically dominant (Puts *et* *al.,* 2006). Bioacoustic studies are used in finding the new populations of different living organisms (Wijayathilaka *et al*., 2018). They are also very useful in determining the effect of the human activities on the vocalization and communication of other living organisms (Warren *et al.,* 2006). Animals show varied behaviors and produce different types of vocalizations during discrete behaviors. An animal produces alarm calls, mating calls and calls for communicating with the other group members. This vocalization depends on the psychological and physiological state of the animals and they produce different types of acoustic signals in different emotional states (Patel *et al.,* 2011). As the technology is developing the use of new instruments and applications is also increasing in the field of bioacoustic studies. With the help of non-invasive techniques, we can extract and analyze the vocalization of different animals in their natural environment so that we can get more precise information about them and also about how the acoustic signals developed and evolved into language (Rauschecker, 2019; Pisanski *et al.,* 2016). A bioacoustic study also assists humans in improving the singing voice as we can monitor the changes in the acoustic parameters due to the vocal training (Mendes *et al*., 2003).

**Sound production and acoustic parameters**

Humans and animals produce acoustic signals with the help of the vocal tract when air passes during exhalation process. The vocalization produced by every individual is unique and this difference in the vocalization is because of the difference in the size and shape of their vocal cords and difference in their body sizes. A different type of acoustic signals produced by the animals and humans is possible due to rapid changes in the shape of the vocal tract of the animals, as a result the acoustic parameters of the sound produced is different in different conditions (Riede *et al.,* 2005; Maxfield *et al*., 2017). Studies suggest that in humans the difference in the vocal tract and vocal folds in men and women are responsible for the difference in the acoustic features due to which we can differentiate the voices produced by men and women (Puts *et al*., 2007). The production and perception of the acoustic system is also controlled by the neural systems (Frühholz and Schweinberger, 2020 and Gruber and Grandjean, 2017). It has been reported that the emotional state of animals such as dogs are affected by the care and handling of the humans and the acoustic parameters in the bark sounds produced by the dogs contain information about their relationship with the handler (Pongrácz *et al.,* 2006). The acoustic signals are observed to evolve. It has been established that in fishes the evolution of acoustic signals is associated with different factors (Ladich, 2014).

**Use of Bioacoustics**

Acoustic signals are produced by both plants and animals and play a significantrole in communication and expression of the emotions of living organisms. All organisms produce vocalization in different situations and the vocalization itself contain much information about the caller and the surrounding environment. The acoustic signals can be used for extracting the information about the caller's emotion, caller's physiological state, psychological state, the effect of surrounding environment on the caller and also about the surroundings of the caller. Many of the behavioural activities of animals depend on their vocalization. A number of animals use their vocalization such as alarm calls as a defensive behaviour to avoid dangerous animals and to protect the other group members.

**Bioacoustics and increased production**

Humans depend on both plants and animals for food and shelter. As the population of humans is increasing, the need of food, clothes and other essential commodities is also increasing. To fulfill these needs, humans are inventing different methods and technologies to increase the production of the food that they consume. As the demand of food is increasing, welfare of the animals in meat industry is also required to get good quality of meat because the quality of the meat is related with the environment, care and handling given to them (Wigham *et al.,* 2018). Bioacoustics can be used in determining the state and weight of the animals so that the growth-related information can be easily collected in early stage of animals (Fontana *et al.,* 2017). As the commercial farming of plants and livestock is increasing, the methods and technologies for their better welfare and growth are also changing. Management and monitoring of large number of animals is a difficult task, but with the help of automated sound detection systems or acoustic monitoring devices and other applications, farmers can easily observe and monitor the animals (Bishop *et al.,* 2019). In commercial dairy farms, the analysis of changes in the foraging behaviour of the animals can be helpful to farmers in detecting the disease or abnormality in animals (Vanrell *et al.,* 2020). There are many problems that farmers face while rearing farm animals and one of the major problem is that they cannot detect the estrus in the farm animals at right time. With the help of a Decision Support System or automated voice detection systems based on acoustic features of vocalization, the farmers can identify the right time of estrus in animals and can artificially inseminate the animals at appropriate time (Devi *et al.,* 2019; Schön *et al*., 2007; Röttgen *et al*., 2018). It is a difficult task to monitor individual behaviour of the animals at farm but with the help of automatic vocalization detection algorithm even ruminating behaviour in animals can be detected (Chelotti *et al*., 2016). Automatic monitoring devices assist farmers in perceiving the information related with the feeding behaviour of the animals in different environmental conditions (Deniz *et al.,* 2017). Bioacoustic tools and applications can not only be used in understanding the vocalization of the large animals but can be of use in detection of the plant pests as well, as the larval stages also produce sound when they dig out holes in the plant (Gutiérrez *et al.,* 2010). Human error can be avoided using automated devices, for recording voices particularly in hostile environments like thick forests, underwater environment and extreme cold habitats.

**Bioacoustics in disease detection**

With advantage of new techniques of bioacoustics, we can identify diseased persons using their acoustic signals because pathological condition also affects the voice of the organisms (Muhammad and Melhem, 2014; Muhammad *et al.,* 2016; Muhammad *et al.,* 2017). Today the world is facing many challenges due to the pandemic disease COVID-19 and the disease is affecting not only the health of the living organisms but also other activities and work of humans. Because COVID-19 disease is mainly affecting the respiratory system of thehumans, so it is also affecting the vocalization of the infected individual. Studies suggest the acoustic parameters of the vocalization produced by infected individuals to be different as compared to the acoustic parameters of a healthy person because infected person suffers breathing problems which directly affects the voice produced by the individual (Asiaee *et al.,* 2020). It is proved that the acoustic features of normal voice of humansare different from the pathological voice (Ali *et al*., 2016). Analysis of gastrointestinal sounds can be done using bioacoustic tools so we can even detect any disorder related with the bowel sound using non-invasive methods (Dimoulas *et al.,* 2007). Acoustic features of both Human and animal vocalization can express their emotions like pain and happiness using the verbal and non-verbal language. Humans are the most developed and advanced among all the living organisms and can express their emotions in verbal language but because others animals do not have verbal language it becomes difficult for humans to understand their emotions. Rearing large number of animals, monitoring all the animals and detecting disease in animals is a difficult task but by using bioacoustic tools and techniques for analysing vocalization of the animals, farmers can not only determine the sex and age of the animals but they can also monitor the distressful conditions of the animals easily (Cordeiro *et al.,* 2018). The farmers face many animal health related challenges caused by disease outbreak in animals and it may also cause a huge economic loss to them. Bioacoustic tools can be a big support to detect the diseases such as respiratory disease in animals so that the farmers can prevent the spread of the disease and can cure the affected animals at the right time (Carpentier *et al*., 2018; Mahdavian *et al.,* 2020) because harmful animal diseases not only harm other animals but they can infect human beings also.

**Bioacoustics in monitoring, identification and conservation of species**

Today climate change and anthropogenic activities are the major threats to many animal and plant species. Monitoring the animals and finding information about them so that we can use appropriate methods for conserving living organisms is important task and can be utilized for good conservation methods and strategies. Different types of animals live in different habitats and it is a real difficult task to monitor and analyze the animals which live in adverse environmental conditions, but bioacoustics makes it possible to analyze the vocalization of animals living in different kinds of habitat like water, dense forest and in desert or in islands using automated devices (Mielke and Zuberbühler, 2013; Gervaise *et al*., 2010). Analyzing marine ecosystem is again a very difficult task but with the help of devices like hydrophones it becomes easier to monitor the marine animals (Pieretti *et al.,* 2017). Bioacoustic tools combined with different algorithm can be used to detect and analyze the vocalization of animals recorded in noisy environment and to analyze the emotional state or other information related to the animal (Venter and Hanekom, 2010; Ramli and Jaafar, 2016). There are many studies which prove that vocalization of animals are emotional indicators (Briefer *et al*., 2015) and by understanding the acoustic signals we can also understand the state of the living organisms and also its surrounding environment and climate. The change in climate also affects the vocalization of the terrestrial and marine animals, so acoustic signals can also be used as an indicator of climate change (Luque *et al.,* 2018; Penar *et al*., 2020). Automated methods can be used for identification and classification of bird species by analyzing their vocalization with the help of non-invasive bioacoustic techniques (Zhao *et al*., 2017; Potamitis *et al*., 2014; Ntalampiras, 2018) and the correlation between the two species of birds can be found using their acoustic signals (Päckert *et al.,* 2004). Today the bioacoustic tools can be of service to analyze the acoustic signals of small insects even with the help of smart phones. Bioacoustic technology can be used in finding new species of animals and analyzing their habitat and distribution (Wijayathilaka *et al*., 2018). Animalsliving in different habitatsare affected by the environmental conditions and many times they migrate from one place to another to survive. Monitoring of animal movements and analyzing their population is possible with the help of bioacoustic tools and applications (Bardeli *et al*., 2010). Humans are surrounded by different animals and they keep some animals like cats, dogs, birds and fishes as pets and their companion. It is important to understand the acoustic signals produced by the animals that are used as pets because the emotional state of the living organisms is also affected by the actions of the other animals living with them. Humans are known to keep many animals in captivity to save them from extinction and save them from poaching, but it is a hard task to raise the animals in captivity without knowing their behaviour. Bioacoustic studies help to understand the acoustic signals produced by the animals in different behavioural contexts.

**Bioacoustics in determining the effect of anthropogenic activities**

Human activities are increasing with the increase in population. Due to this, pollution is increasing and affecting all other organisms which live in the same environment. Terrestrial organisms, birds as well as marine animals are getting affected by the human activities. By combining the bioacoustic tools with new technologies, changes in the distribution, behaviour of animals and other effects of anthropogenic activities on animals can be monitored and analyzed correctly (Buxton *et al.,* 2018; Mammides *et al.,* 2017). There are evidences that the vocalization produced by the bird species living in urban areas produce loud acoustic signals as compared to the birds which live in forests to nullify or neutralize the effect of anthropogenic noise (Nemeth and Brumm, 2009). Using bioacoustics, the animals which are affected by the toxic substances released by human activitie scan be identified because the acoustic features of affected organisms are different as compared to the healthy organisms (Salgado Costa *et al.,* 2018). The anthropogenic noises cause change in the behaviour of animals and their calling rates (Sun and Narins, 2005). Human activities have severe consequences of habitat fragmentation and destruction and are responsible for the shifting of the habitat or housing grounds of the animals (Barber *et al.,* 2009) and this is affecting the life cycle of the animals. During breeding season many organisms produce mating calls to attract their mates but they may face the problem of masking due to the traffic noises which affects their calls. Many anuran species can alter their vocalization so that the anthropogenic noises cannot mask or affect their mating calls (Cunnington and Fahrig, 2010). Increase in the anthropogenic activities in water bodies causes pollution in the aquatic environment by masking the acoustic signals produced by the marine animals and is responsible for the disturbance in their communication system or interaction with the conspecifics (Erbe *et al.,* 2016; Garrett *et al.,* 2016).

**Bioacoustics in behaviour analysis of animal calls**

Animals display different types of behaviour and acoustic signals in different situations from birth and the changes in the behaviour of the animals is also related with the changes in their surrounding environment. Both adult and juvenile animals can use acoustic signals to show their aggressive behaviour due to competition for space and food (Bertucci *et al.,* 2012). Animals recognize the vocal signals produced by their group members and can differentiate the vocalization of closely related group members with others. The new born animals can recognize the vocalization of their mother and the calves can recognize the acoustic signals produced by the dams (Marchant-Forde *et al.,* 2002) and become distressed when separated with each other (Weary and Chua, 2000). Studies suggest that cows produce two different types of contact calls which have different acoustic structure and these calls are related with different behavioural situations of the animal (de la Torre *et al.,* 2015). Acoustic signals produced by animals in different life stages and different situations they face during their life cycle, are different. The acoustic signals produced by animals to communicate with the conspecifics, alarm calls and calls produced during breeding season i.e., mating calls to attract the animals of opposite sex of the same species are totally different from each other. Animals also produce acoustic signals in response to the food to give information about the food to the other group members (Clay and Zuberbühler, 2009; Di Bitetti, 2005). The food related calls are also associated with the type and quantity of food the animals receive and also which group member discovers the food first (Gros-Louis, 2004; Slocombe and Zuberbühler, 2006). The acoustic signals are very important for reproduction in many anurans and bird species and these mating calls are much affected by the environment and also by the mating calls of the animals of the same species (Tobias *et al.,* 2004). Modern technologies provide many tools to monitor the acoustic signals of the animals clearly and also the changes in their vocalization due to anthropogenic activities, climate change and land use changes (Pieretti *et al.*, 2011). Japanese great tits birds produce alarm calls to inform other group members about the predator and their alarm calls even contain information about the predator i.e., they produce different alarm calls according to the type of predator (Suzuki, 2014). While producing alarm calls, many animals give information not only about the type of predator but also the urgency to escape from the predator (Manser *et al.,* 2002).

## Conclusion

Animal bioacoustics is an interesting field of research. The analysis of studies presented in this literature shows that the bioacoustic technologies can be used in decoding information related with the behaviour of the animals, their interaction with other animals, emotional and individual information of animals, their physiological state and also about the environment in which the organisms live. Bioacoustics can be used as a tool in solving many problems related with rearing animals, determining diseases in early stage or to understand the behaviour of the living organisms. Today, automatic bioacoustic monitoring devices and algorithms help a lot in monitoring and classification of the animal vocalizations (Armitage and Ober, 2010; Truskinger *et al.,* 2015). The anthropogenic noises have both positive and negative effects on an animal which live near them because anthropogenic vocalizations can mask the vocalization of the animals and they cannot communicate with their group members. But owing to the anthropogenic noises, some animals manipulate or evolve their acoustic signals so that they can communicate with their conspecifics. There are still many fields which are associated with the acoustic signals and the information behind them is yet to be discovered. Bioacoustic studies are providing us the new vision to learn about the relation of the acoustic signals with the behaviour, surroundings and health of the organisms. Animal vocalization thus, has an explicit association with their conservation.

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