Journal of Animal Environment
(E-ISSN 2717-1396, ISSN 2717-1388)
Journal homepage: https://aejournals.org/

Original Research Paper

Bio Acoustic Intelligence Model for Non-Invasive Wildlife Behaviour Monitoring and Conservation Assessment

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Key Words

Bioacoustic monitoring, Animal vocal behaviour, Non-invasive assessment, Wildlife conservation, Animal welfare indicators, ethology.

Abstract

Monitoring of wildlife behaviour is an important aspect of conservation biology, but the traditional methods of field observations and samples collection are known to disrupt animals, interfere with natural behaviour expression, and create logistic and ethical challenges especially with regard to elusive, nocturnal, or endangered species. Vocal communication is an example of biologically based and non-invasive means of understanding animal's behaviour, physiological condition, and social context without manipulating an animal directly. This paper develops a framework referred to as BioAcoustic Intelligence Model (BAIM). It is an application of knowledge obtained in the field of animal behaviour that classifies naturally occurring vocalization patterns into meaningful categories such as distress, territorial calls, courtship behaviours, alarms, and contact vocalizations. Using ethological, biological principles of vocal communication, and conservation behaviour, the model establishes the connections between acoustic behavioural categories and animal welfare, reproduction, habitat use, and stress within population. The paper will discuss the model in terms of its applicability to different taxa, possible limitations associated with identification of individuals and variability of calls depending on social context, and incorporation into monitoring programs.

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Received: 25th May, 2026; Revised: 6th June, 2026; Accepted: 8th June, 2026; Available Online: 07th August, 2026 (DOI): 10.70102/AEJ.2026.18.3s.99

Introduction

The behaviour of wild animals, their communication, and reactions to changes in the environment have been an issue of fundamental importance for animal science and conservation biology. While the traditional ways of studying the condition of animals, such as direct observation, trapping, radio-telemetry, and physical manipulation, have continued to be popular techniques, the one drawback of all of these methods is that they may influence the behaviours that are being observed in the process. Capture and restraint stimulate the release of stress hormones, disturb social structures, and cause animals to avoid the researchers after the study session is over (Mcloughlin et al., 2019).

The use of vocal communication represents another avenue to investigate animal behaviour without the need for an observer to be physically near the animal or the need to touch, restrain, or remove the animal from its environment. Vocalizations occur all the time in the context of normal behaviours associated with sociality, reproduction, and defence and provide information regarding the physiological and emotional state of the producing animal (Mcloughlin et al., 2019; Teixeira et al., 2019). Since sound travels far beyond the visible and can be passively recorded over long periods of time, vocal behaviour studies are being used more and more frequently in animal science and conservation practice as a tool for investigating animals which are otherwise very hard to observe directly (Wrege et al., 2017).

This paper introduces the BioAcoustic Intelligence Model (BAIM), which is a model constructed based on animal behaviour science instead of a signal processing or engineering approach. The model considers vocalization as a behavioural event similar to other behaviours such as posturing, grooming, foraging, and classifies it according to its ethological purpose. The aim of this model is to provide a tool for behaviour and conservation monitoring in the wild by providing a basis for vocal output based on principles of animal communication, motivation, and well-being science so that vocalization observation becomes equally as behavioural as visual behaviour observation.

Key Contributions

- Advances a bioacoustics model for non-invasive monitoring and conservation evaluation of wildlife behaviours.
- Classifies animal vocalizations based on behavioural aspects associated with welfare, reproduction, and habitat utilization.
- Contributes to the long-term monitoring of wildlife conservation via ethological analysis of animal vocal behaviours.

This paper continues as follows. The following section explains vocal behaviour as a biological signal. The BioAcoustic Intelligence Model is explained in Section 3, behavioural and physiological indicators from vocal behaviours are described in Section 4, conservation applications are listed in Section 5, limitations and directions for the future are presented in Section 6, and Section 7 concludes the paper.

Vocal Behaviour as a Biological Indicator

Animal vocalizations are not accidental by-products of their physiology but are evolutionary adaptations that communicate particular messages to other animals, predators, or rivals (Teixeira et al., 2019). Alarm vocalizations communicate the presence of danger and vary acoustically depending on the nature of the danger and its immediacy. Contact vocalizations are used for maintaining social cohesion between animals in a social unit or between parents and offspring, and their rate and regularity indicate the strength of social relationship. Territorial and advertisement vocalizations convey signals of reproductive state, dominance, or ownership of resources, and their production rate is usually dependent on the breeding season and population density. Distress vocalizations, however, are generally made in situations involving pain, physical restriction, social isolation, or danger (Mcloughlin et al., 2019; Romero-Mujalli et al., 2021).

Since all call types are associated with particular behavioural and motivational conditions, the occurrence, rate, and temporal patterns of calls can be used as indirect indicators of behaviour in situations where the animal cannot be seen. It is exactly this biological principle that underlies the BioAcoustic Intelligence Model: calls are considered as a continuous record of behaviour, which is analogous to an activity record, from which meaningful states can be identified by the same principles as actual behaviour.

Structure of the BioAcoustic Intelligence Model

The five primary functional categories into which the BioAcoustic Intelligence Model classifies wildlife vocal behaviours include those based on contact or affiliation, territory or advertisement, mate attraction or courtship, alarm or predator response, and distress or agonism. In each of these cases, there is a specific behavioural context, rate of frequency expected in a healthy population, and seasonal or diurnal pattern for that behaviour (Teixeira et al., 2019; Ruff et al., 2020). For example, contact calls among social mammals would be expected to occur at a steady rate indicative of healthy social cohesion, while distress or isolation calls occurring at a high rate would be behaviourally consistent with social, physical, or environmental disruption.

In order to avoid using the invasive sampling method for setting such baselines, the model utilizes the passive recording from listening posts at constant positions within the habitat of the animal, in accordance with the well-known techniques of acoustic surveying of elephants, birds, amphibians, and primates in conservation biology (Wrege et al., 2017; Ruff et al., 2020; Dufourq et al., 2021). The listening posts are arranged in such a way as to register the natural vocal behaviour during the day-and-night cycles and over the seasons, without disturbing the movement of the animal, or any need for being present near the animal. The behaviour thus recorded is then evaluated relative to the known vocal repertoire of the species in question from the literature of animal behaviour, where the calls

are classified according to function (Schneider et al., 2022).

One of the main advantages of this structure is that it relies on the science of comparative animal behaviour rather than any particular technology used to record and analyze the data. The framework determines what needs to be measured, i.e., the distinctive types of calls and how they are arranged in time, and why it is important for well-being and conservation purposes, whereas the exact method of measuring sound becomes a secondary aspect of the entire project.

Behavioural and Physiological Indicators Derived from Vocal Monitoring

If vocal categories are monitored overtime, many conservation indices follow straightforwardly from animal behaviour science principles. The onset of reproductive behaviour can be determined based on the seasonality and frequency of mate-attracting calls and territorial calls, which provide a less intrusive measure of the breeding cycle, as nesting and mating behaviours need to be observed to determine it (Ruff et al., 2020). The stress level in a population can be estimated using prolonged levels of distress and agonistic calls compared to a previously set baseline, as there is evidence of the connection between the levels of vocalization and hormones in mammals and birds (Mcloughlin et al., 2019; Romero-Mujalli et al., 2021). Social cohesion in a group can be determined by monitoring affiliative calling, because when a group becomes fragmented, the level of vocal communication tends to become erratic (Teixeira et al., 2019).

The same could apply to the inference of occupancy and use of ranges based on the spatial distribution of species-specific vocalization on a landscape level, which has already been shown possible for forest elephants and other vocally active species in dense or hard-to-reach habitats (Wrege et al., 2017). These measures are based on animal's spontaneous behaviour and are therefore free from the problem caused by the presence of observers or any kind of handling; besides, they can be obtained even during the seasons when it is practically impossible to conduct field observations, for example, during nights or bad weather conditions.

This system is also able to be used in conjunction with comparing an individual's vocalizations with known repertoires that have been described using traditional ethology, where deviations in calling rate, call repertoire, and call co-occurrence can be determined to be behaviourally abnormal. These deviations are seen in a conservative light as potential indications that require further non-intrusive study.

Applications in Conservation Assessment

When implemented as part of a conservation program, the BioAcoustic Intelligence Model serves various practical assessment purposes. Firstly, it makes it possible to detect the presence and relative numbers of secretive or sparse species without visual verification, complementing existing techniques in surveys of

species like forest primates, nocturnal carnivores, and canopy birds (Dufourq et al., 2021). Secondly, it gives an opportunity to detect behavioural disturbance following habitat alterations, human intrusion, or unusual weather phenomena, as changes towards higher distress and less affiliative calls can be detected long before population numbers drop via traditional counting methods. Lastly, it gives a means of welfare-based assessment of managed or semi-managed wildlife populations, like rehabilitation centres and preserves, where constant non-invasive behaviour monitoring is more beneficial than periodic manipulative welfare assessments (Romero-Mujalli et al., 2021).

Given that the output from this model is behavioural or ethological in nature rather than acoustic, it can easily be integrated with existing conservation assessment methods that incorporate behaviour, including activity budgets, reproductive success, and social cohesion measures. Such integration means that the vocal monitoring data can easily be incorporated into conservation assessments along with traditional field behavioural observations without discounting animal science methods.

Limitations and Future Directions

There are several factors to consider in this regard. Repertoire of vocalizations and function of a call type can differ from population to population, between age categories, and between individuals. Moreover, a particular call type linked with one behaviour in one situation can mean something entirely different in a completely different environment and social setting (Teixeira et al., 2019; Schneider et al., 2022). Thus, it is necessary to establish baseline data for each species and population with direct behavioural observations first to be able to interpret vocalization monitoring results reliably. The absence of any sound is not always an indicator of the absence of an animal, as some species vocalize rarely or seasonally and only under certain social circumstances.

Further research needs to focus on the longitudinal validation of vocal behaviours with regard to direct observations and physiological parameters such as glucocorticoid metabolites found in faeces. This research can be conducted across a larger set of taxonomic groups and habitats. Building up a species-specific library of vocalizations is key for the advancement of models such as this one.

Conclusion

In the BioAcoustic Intelligence Model, the animal vocalizations are considered a primary, biologically relevant source of information about the behavioural status of the organism, not an indirect behavioural indicator. This method provides conservationists with a truly non-invasive tool for evaluating such parameters as reproductive behaviour, social stability, habitat suitability, and disturbance in the natural animal vocal behaviour, based on the well-studied principles of animal communication, motivation, and animal welfare science. The relevance of the approach does not depend on the technique of capturing acoustic signals, but on the ethological rationale linking animal vocalizations to the key issues related to conservation (breeding, stable group structure, suitable habitat, and no behavioural stress). The

use of such an approach in combination with behavioural observations allows for the development of wildlife monitoring methods, less invasive for animals and more informative for conservationists.

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