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LETTER TO THE EDITOR

Passive acoustic monitoring as a complementary strategy to assess biodiversity in the Brazilian Amazonia

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Environmental Impact Assessment (EIA) is a conservation instrument used to analyze and identify projects with potential environmental impacts, ultimately, providing mitigation strategies for decision-making (Ritter et al. 2017). In a timely debate on the conservation of the Amazon rainforest, Ritter et al. (2017) produced an essential discussion about EIAs, and reviewed three recent EIAs from infrastructure projects linked to current threats in the Brazilian Amazon basin. The authors highlighted shortfalls regarding biodiversity assessments in EIAs for the concession of roads, hydroelectric facilities and mining activities, and provided guidelines for three innovative and cost-effective methods to cope with highly diverse ecosystem: satellite remote sensing, species spectral signature, and DNA metabarcoding (Ritter et al. 2017). Although these methods are promising tools, we believe that practical solutions to sample and monitor biodiversity at large spatial and temporal scales should also take advantage from Passive Acoustic Monitoring (PAM), a reliable and cost-effective method that recently became widely employed to assess and monitor multiple animal taxa. Here, we advocate the use of PAM as an alternative and/or complementary tool for EIA in the Amazon basin.

Sounds produced by animals have long been used to assess biodiversity (e.g., point counts for birds, and standardized acoustic transect for amphibians). Although being an effective method to detect species, its use is mostly constrained by the availability of specialists (e.g., ornithologists) to conduct fieldwork (Sueur et al. 2012). In addition, auditory monitoring is rarely replicable over large temporal and spatial scales in tropical

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forests. Recently, both commercial and low-cost Automated Acoustic Recorders (AAR) have become available, and their use for biodiversity assessment with PAM increased, rapidly becoming a cost-effective alternative for Rapid Biodiversity Assessment and All Taxa Biodiversity Inventory (Sueur et al. 2008; Wrege et al. 2017).

PAM offers programable settings for efficient wildlife recording in different habitat types, with an estimated battery and storage autonomy (Sueur et al. 2012). A sampling protocol of PAM composed of a network of AAR deployed to monitor different places simultaneously can be applied to standardize sampling designs and properly cover spatial and temporal scales in EIA (Sueur et al. 2012). Because microphones are sensible to different frequency ranges, recordings capture a wide variety of animal taxa (biophony), including cryptic and endangered species (Campos-Cerqueira and Aide 2016; Wrege et al. 2017). Additionally, PAM allows the recording of sounds produced by geophysical elements (geophony), as well as sounds produced by human activities (anthropophony; Sueur et al. 2014; Schmeller et al. 2017). These elements represent, together, an acoustic context that characterizes an ecosystem (soundscapes), whose changes through time and space can reveal how biodiversity responds to impacts from human activities (Sueur et al. 2014; Deichmann et al. 2017; Schmeller et al. 2017). This flexibility allows inventorying and monitoring species from a permanent database that remains accessible anytime, and does not require the presence of experts for fieldwork (Sueur et al. 2012; Campos-Cerqueira and Aide 2016). Species vocalizations can be identified and further be incorporated in acoustic scientific collections (e.g. The Macaulay Library, Fonoteca Neotropical Jacques Vielliard-FNJV, Automated Remote Biodiversity Monitoring Network-ARBIMON, and Fonoteca Zoológica-FonoZoo).

Another important advantage of PAM is the ability to directly assess noise pollution (Schmeller et al. 2017). Noise pollution can affect wildlife through changes in species behavior, mating, foraging, and movement patterns, of which impacts can scale up to population and community-level responses (Shannon et al. 2016). Empirical studies pointed noise from mining activities and road traffic as a significant driver of biodiversity declines (Duarte et al. 2015; Ware et al. 2015; Machado et al. 2017). All three infrastructure projects in Amazonia assessed by Ritter et al. (2017) present high levels of noise pollution, however, the potential impacts of noise on terrestrial and aquatic fauna in the Amazonia remains overlooked. The assessment and monitoring of these sources of noise and consequent biodiversity responses with the advent of PAM can improve the understanding of noise pollution on wildlife and support both the conclusions and guidelines of EIA.

While PAM can significantly improve temporal and spatial coverage of species monitoring in EIA, an operational challenge is to extract useful biological information from the massive amount of data that can be acquired (Gasc et al. 2017). In general, there is a tradeoff among time spent listening the recordings and the number of calls identified at the species level (Sueur et al. 2012). Fortunately, there are new tools to manipulate and extract information from large audio files, such as R packages (e.g., seewave, pumilioR and warbleR) and online tools such as the Remote Environmental Assessment Laboratory (REAL), ARBIMON, and Ecosounds (Gasc et al. 2017). Moreover, automated species-identification algorithms can be used to detect species in the recordings, although it usually focuses on a small set of species, since most algorithms are species-specific (Campos-Cerqueira and Aide 2016). On the other hand, soundscape analyses do not require species-level identification, once it represents an acoustic context, and can be used for example, to compare biodiversity patterns from different areas (Deichmann et al. 2017). Although soundscape analyses and automated species-specific identification have been successfully used to estimate animal distribution, species richness, and to assess natural and anthropogenic noise impacts on the fauna, these new approaches keep changing through continuous development and enhancement, and should therefore be used wisely (Sueur et al. 2014; Campos-Cerqueira and Aide 2016).

The development of PAM, along with the quantitative tools to process acoustic recordings and extract information of biodiversity allows us to assess and monitor entire ecosystems (Sueur et al. 2012; Schmeller et al. 2017). PAM can be a valuable tool for Environmental Impact Assessments, once its application can improve the procedures related to species inventory, detection of threatened and rare species, standardized protocols for sampling, and to detect human impacts on biodiversity (Sueur et al. 2012; Schmeller et al. 2017). PAM is a standardized, non-invasive method successfully used to assess marine, freshwater, and terrestrial systems to deal with a range of ecological and conservational questions (Sueur et al. 2014). For this reason, we recommend the use of PAM as a key strategy for biodiversity assessment, supporting the spatial and temporal scopes expected in EIA.

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