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The effect of natural noise and conspesific sound density on the prevalence of *Leptophryne borbonica* Tschudi, 1838 displaying visual signals

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ABSTRAK

Mode komunikasi utama dalam anura adalah sinyal akustik, tetapi kebisingan lingkungan dapat menghambat efektivitas pemberian dan penerimaan sinyal. Adaptasi yang dilakukan adalah memancarkan sinyal visual. Penelitian ini dilakukan untuk mengetahui kepadatan, jenis sinyal visual yang terdeteksi, dan apakah ada pengaruh kebisingan lingkungan dan juga kepadatan konspesifik terhadap prevalensi individu Leptophryne borbonica *yang memancarkan sinyal visual. Penelitian ini dilakukan dengan metode deskriptif dengan teknik purposive sampling. Data yang diambil berupa jumlah individu visual, jumlah individu yang membuat kebisingan, dan kebisingan lingkungan sekitar. Data diolah menggunakan Solomon coder dan dianalisis dengan regresi poisson. 159 individu katak ditemukan di 40 plot selama pengamatan, dengan kepadatan individu di setiap plot adalah 3 hingga 8 individu dengan kebisingan rata-rata 45 hingga 74 dB. Jadi dapat disimpulkan bahwa kebisingan secara signifikan mempengaruhi emisi sinyal visual oleh masing-masing katak individu, sedangkan kepadatan konspesifik tidak mempengaruhi dalam output sinyal visual*.

Kata kunci: Anura, Bodogol, Jawa Barat, komunikasi hewan, Solomon coder

ABSTRACT

The main mode of communication in Anura is acoustic signals, but environmental noise can hinder effectiveness signal transmission and reception. The adaptation to noise is by visual signals. This study was conducted to determine the density, the type of visual signals detected, and whether there is an influence of environmental noise and conspecific density on the prevalence of Leptophryne borbonica *population displaying visual signals. This study was conducted by descriptive method with purposive sampling technique. The data taken was in the form of the number of individuals with visual signals, the number of individuals vocalizing, and the noise of the surrounding environment. The data was processed using the Solomon Coder and analyzed by Poisson regression. 159 individual frogs were found in 40 plots during observations, with the density of individuals in each plot being 3-8 individuals with noise range of 45-74 dB. Noise significantly affected the display of visual signals in a population, while conspecific density did not affect the output of visual signals*.

Keywords*: *animal communication, Anura, Bodogol, Solomon coder, West Java

INTRODUCTION

As nocturnal animals active in low-light environments, frogs use acoustic signals as the primary mode of communication (Genhard & Huber, 2002, Wells 2007). However, some frogs have issues with the effectiveness of acoustic signals transmittion, especially noise disturbances on the surrounding environment. The noise produced by the surrounding environment can inhibit the effective signal transmittion and acquisition, so that it will also affect the effectivenes of acoustic signals in the frog (Narins & Zelick, 1988; Brumm, 2013). If the acoustic signal is not conveyed properly to the receiver, the information conveyed is also less clear.

Ambient noise can cause a weakening of the effectiveness of acoustic signals, so some frogs are known to have adapted by modifying the frequency and duration of the acoustic signal to stand out in the midst of noise, by increasing the intensity of sound so that it can adjust flexibly to reach the signal depending on the noise of the surrounding environment at a distance from the receiver (Grafe et al., 2012).

However, a common adaptation made by frogs is to release an alternative mode of communication, including visual signals (Hodl & Amezquita, 2001). Visual signals are performed as a backup of acoustic signals to complement the acoustic information. Visual signal is information that is visible to receiver, and performed by some species of frogs that inhabit noisy environments usually creeks and fast-flowing rapids in the mountains (Blumm & Slabbekoorn, 2005). Visual signals in frogs are displayed in various social interactions where some signals are known to have quite specific roles. There are about 20 types of visual signals displayed by anurans (Caldart et al., 2014), such as lifting the body, lifting the legs, and leg movements. Related to distance, visual signals are generally only carried out in close interactions because the efficiency of visual signals is not very good at long distances, especially in low light conditions (Cummings et al., 2008).

In relation to the priority of modality use, visual signals are generally only displayed as a backup of acoustic signals. This signal is performed under certain conditions, such as when environmental noise level is very high and interferes with the acoustic signal. Despite this, most studies focus on the individual level, but no studies have looked at the population scale (Lindquist et al., 1996; Toledo et al., 2007). If noise is one of the main determinants of visual signal display, then the prevalence of this signal will be high in frog populations occupying very noisy habitats, whereas its prevalence will be very low in quiet locations.

Moreover, referring to the display of visual signals, the results of existing research still debate the function of visual signals as territorial advertisement signals to strengthen detectability and locatibility. This signal can be displayed not only limited to the presence of visual cues (close interaction), but also triggered by other factors. One of them is conspecific density. The conspecific density common to nocturnal frogs, indicated by the high number of voiced individuals assumed to be one of the triggers for the release of visual signals in complex environments. Although frogs are not able to detect the presence of other individuals visually, if the frog is able to detect it using other cues (acoustics), then visual signals may be issued as an advertisement function enhancer, for example in attracting the attention of prospective female mates. Because visual signals are quite risky, individual frogs tend to display these signals after confirming the presence of signal receivers around them. So that in low density conditions, visual signals will be displayed but at a very basic level, or called as baseline rate (Pope, 2000).

This study focused on a species of hourglass frog (*Leptophryne borbonica*), a species active in rapids which noise is a potential interference with acoustic communication. The purpose of this study was to determine whether there is a correlation between the intensity of environmental noise and also the density of conspecific to the prevalence of individual frogs emitting visual signals. It is interesting to study how the influence of noise and conspecific density on the prevalence of visual signals of *L. borbonica*) in PPKA Bodogol Gunung Gede Pangrango National Park.The results of this study are expected to increase knowledge about the effect of noise and conspecific density of vocalized individuals on the prevalence of visual signals in *L. borbonica* and become a source of information for related researchs.

METHODOLOGY

Studies sites and species sampling

This research was conducted in May-June 2023 at Cisuren Rapids, Bodogol Nature Education and Conservation Center (PPKAB), Gunung Gede Pangrango National Park.

Survey design

We use transects that are lined following the flow of the rapids along 200 m. Along the transect, four 5x10 meters plots are purposively laid with a minimum distance between plots along 5 m. These four positions are purposively done to capture different noise variations, while the minimum determination of the distance between plots of 20 m aims to avoid bias due to interference from data collection between plots. The transect is applied in a rapids, called Cisuren. Observations of frogs in both rapids were carried out alternately. The same transect in each rapid is carried out as many as 5 repetitions (visits) for frog observation. Each frog that has been observed is characterized by photographing the ventral part of each individual found before being released back into its habitat.

Field orientation

Field orientation is the initial stage of introduction to the conditions of the data collection location. Field orientation is aimed at confirming the presence of frogs, mapping, and planning data collection by matching conditions in the field.

Plot creation

Transect determination is applied following the flow of the rapids along 200 m. By applying a plot measuring 5 x 10 meters as many as 4 plots arranged purposively with the distance between one plot and the next varies. Because the size of the two rapids is not too wide (about 2m), the 5x10 meter plot used can accommodate all parts of the rapids (banks and middle), to maximize the encounter of frogs using different substrates. Observations were made at night (18.00—23.00) by making 40 plots scattered along transects in the Cisuren Rapids. Cisuren Rapids is a shallow, and clear rapids suited for *L. borbonica* individuals. Cisuren Rapids is known to be a site with a relatively more abundant amount of *L. borbonica* than other locations in Bodogol (Ardiansyah et al, 2014).

Observation of visual behavior

L. borbonica individuals to be observed are vocalizing individuals. The search for vocalized individuals is carried out slowly in a plot measuring 5x10m using a white flashlight. When individual frogs are detected by observers, white flashlights are replaced with red ones to avoid stress on the frogs to be observed. After the frog individual was found, the individual was then recorded by focal sampling using a SONY DCR-109 night vision handycam for 3 minutes. Given that *L. borbonica* individuals sometimes interact very closely with each other, visual observation needs to be done carefully to avoid disturbing other male individuals that have not been observed. In addition, to avoid error data recorded as a result of frogs stressed due to observation preparation, for example the handicam pre-setting, this study will use pre-recording for 3 minutes.

Environmental noise measurement

Environmental noise is measured using a sound level meter with the EXTECH brand type 407736. Noise measurement was carried out at four points, those are at each corner of the plot and then calculated the average. The position of the sound level meter is 10 cm above the water level. Measurements are made to determine the relative dB. The noise measured in each plot is natural noise emitted by a wide variety of sources, such as rapids noise, noise from conspesific frogs, noise from congeneric frogs, and noise from other natural sources. Given that natural noise varies between space and time, noise recording is repeated at different times on the same plot.

Observation of vocalized individuals

Observation of vocalized individuals is carried out by counting the number of vocalized conspecific individuals. This calculation is carried out by scanning sampling in 1 plot for 10 minutes and is carried out before the visual signal observation stage is carried out. Two observers scanned a plot measuring 5x10 m to calculate the number of vocalized and mute individuals. The two observers will count from the rapids bank with opposite observation points, that is each observer will be on a different side of the rapids.

Data analysis

The recordings are then digitized into a computer to further observe the presence of visual signals in each individual using Solomon Coder application, which is an application that serves to help identify specific behaviors of a type through recorded videos. Visual signal types were identified following Hodl & Amezquita (2009), such as lifting the body, lifting the legs, and leg kicking (leg movements). The visual signal data observed is only the presence-absence data of each visual type issued. Poisson regression was used to determine the effect between total individual density, density of vocalized individuals, and environmental noise on the prevalence of individual frogs displaying visual signals

RESULTS AND DISCUSSION

Abundance and density of *Leptophryne borbonica*

L. borbonica can be found in the Cisuren Rapids at almost every time of the season because this species breeds throughout the year. This species can be found in terrestrial environments but is mostly found not far from aquatic environments (semi-dependent stream) (Brasileiro et al., 2005). Especially during breeding, *L. borbonica* gathers in aquatic environments in colonies (chorus). The characteristics of the aquatic environment preferred by these frogs for breeding are clear water and medium currents with a fairly high availability of seepages (Malkmus & Brühl, 2002).

Of the 40 plots scattered along the transects in the Cisuren Rapids, 159 individuals were found. Individuals were found in each observation plot with a range of 3-8 individuals with an individual density in each plot of 4.8±1.4.

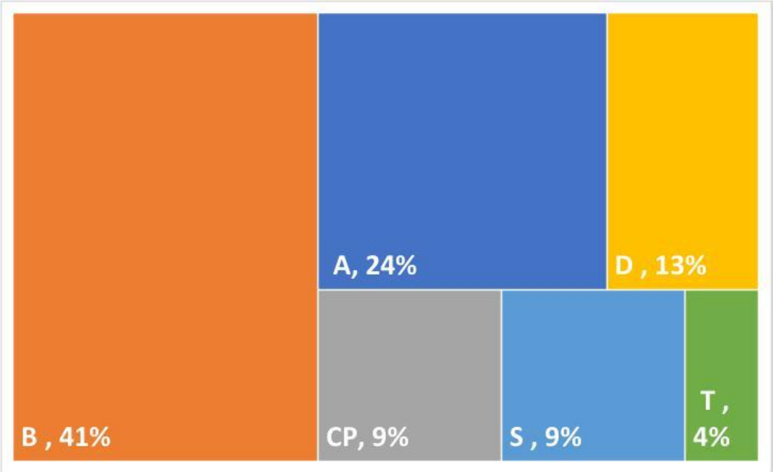

FIGURE 1. Substrate *Leptophryne borbonica* (A= Root, B= Stone, CP= Tree branches, D= Leaf, S= Litter, T= Soil).

Figure 1 showed that *L. borbonica* was found on six substrates, rocks, leaves, tree branches, soil, tree roots, and litter (**Figure 1**). Of these substrates, *L. borbonica* is most found in rock substrates and the least found is in soil substrates. The selection of stone and root substrates as the most widely used perches because stones and roots have a similar color to the body. This is related to several species of Anura that generally use substrate as a disguise so that the substrate chosen is a substrate with a color like its body color to avoid attacks by predators. In addition, the selection of stone as a substrate provides an advantage for frogs to both vocalize (acoustic signals) and visual (visual signals) that are not easily obstructed by physical obstacles around them (Caldart et al, 2014) because rock substrates are generally higher and exposed to less physical obstacles (Noer, reviewed). Iskandar (1998) reported that *L. borbonica* is often found around clear and fast-flowing rapids, this frog is often found attached to short herbaceous leaves around rapids, some others are found on the surface of the soil or rocks around the watercourse. In this study, the soil substrate is the least because the Cisuren Rapids itself is a rapid whose right and left banks are dominated by stone substrate, so it is very rare for frogs to be found in soil substrate.

Types of visual signal in *Leptophryne borbonica*

Acoustic signals are the primary form of communication in nocturnal environments, as they are effective in conveying information in dark conditions (Duellman & Trueb 1994; Hartmann et al. 2005; Wells 2007). However, nocturnal Anura usually uses an alternative means of communication, especially visual signals. (Amézquita & Hödl 2004). We present here some types of visual signals detected *in L. borbonica* during observations.

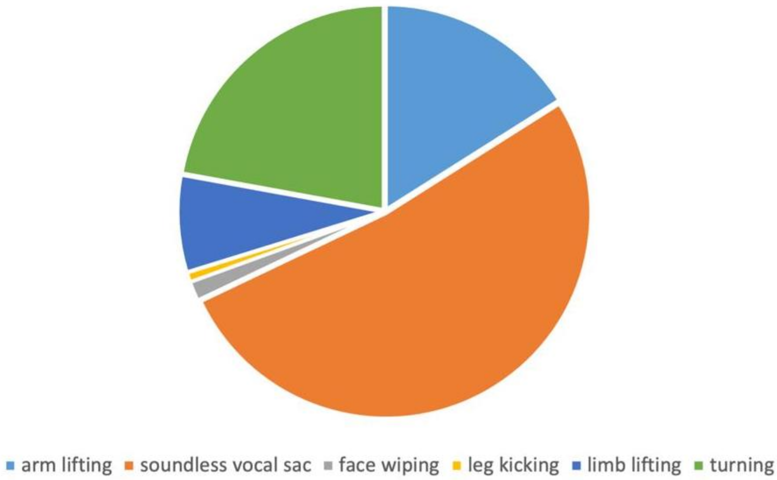

FIGURE 2. Precentage of visual signal.

Figure 2 showed that the visual signals most often displayed by *L. borbonica* individuals are soundless vocal sac and turning, while the least displayed is leg kicking. Soundless vocal sac is released with very high intensity because it is a by-product of acoustic signals, because this visual signal is an interlude from the movement of vocal bags when frogs vocalize. Although soundless vocal sac is only a by-product, this signal can be understood by the receiver (Partan & Marler, 2005). The visual stimulus generated along with the acoustic signal can serve to improve the receiver's ability to pay attention to a given call. The repeated pulsation of the vocal sac in contrast to dark conditions can provide an easily detectable source of information other than using acoustic signals (Rosenthal & Ryan, 2004). Signals with visual and acoustic components such as these can also reinforce information (Rowe, 1999). This combination of acoustic and visual signals serves to improve spatial localization (McDonald et al, 2000). Multimodal stimuli (both acoustic and visual) trigger more visual signal responses than unimodal stimuli. Preininger et al., (2013) mentioned that vocal sacs act as visual cues to improve acoustic signal detection and differentiation by making them more prominent to receivers amid high ambient noise.

The next most commonly shown visual signal is turning. Turning is usually issued to control the direction towards another individual or as an attempt to turn away from threats (King et al., 1996). Under conditions during observation turning is not the main signal, but usually this visual signal is issued as a by-product of other visual signals. Turning is thought to be a product of other visual signals because of things that are not intentionally done for example during limb lifting, when lifting the frog's legs unconsciously change its direction even though it is not with the aim of turning away

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from threats. Turning describes a group of behaviors in which the observed individual directs the body in different directions without shifting. Turning movements are characterized by lifting each leg sequentially (Amézquita & Hödl, 2004). In addition, turning is usually a form of response to another conspecific individual's call. So, *L. borbonica* accidentally pointed its body at the source of the sound. Actually, there has been no further research on the clarity of the function of turning as a visual signal. But research conducted by Amézquita & Hödl (2004) states that turning is a visual signal as the frog indeed makes a movement.

The signal that is least displayed during observation is leg kicking. Leg kicking is usually identical to an aggressive signal, meaning that this signal comes out if the frog has a confrontation with another frog. During observations it was not detected that frogs were confrontational, but signals of aggressiveness may appear in close interactions between males. The leg kicking signal is allegedly a ritualization signal that develops from the physical aggressiveness of frogs that often kick using their hind legs. The few leg kicking signals issued are thought to have not had too many interactions between males encountered during the study, although this study has not been able to confirm this because there were no recorded types of interactions (aggressive, mating, territorial, etc.) in the analysis.

The effect of noise on conspecific density

The noise level of the surrounding environment varies from 45-74 dB with an average noise of 62.3±7.3. The noise, conspecific density, and total individual density data were then analyzed using Poisson regression to see if noise and conspecific density influenced visual signal production in L. borbonica.

From the Poisson regression analysis (**Figure 3**), both noise and conspecific density are significant to the release of visual signals in *L. borbonica* individuals ($Z = 3.853$, $p > 0.05$). Both factors play an important role in the release of visual signals by each individual frog, but the most important factor is noise indicated by high MSE and NodePurity values (pictured).

The correlation between noise and visual signal probability

Figure 3 showed that the noisier a plot is, the more *L. borbonica* individuals display visual signals. Conversely, if the noise level in a plot is low, *L. borbonica* individuals that display visual signals will be less. Noise affects the prevalence of visual signals displayed by *L. borbonica* individuals because the noisy surrounding environment can hinder the delivery of information through acoustics, thus requiring additional signals to clarify the message. Penna & Meier (2011) mentioned that increasing acoustic duration and showing multimodal displays (both acoustic and visual) is a form of response due to the noise of the surrounding environment. So high ambient noise is the main determinant of visual signal emission, hence the prevalence of visual signals will be high in frog populations occupying very noisy habitats, otherwise the prevalence will be very low in quiet locations.

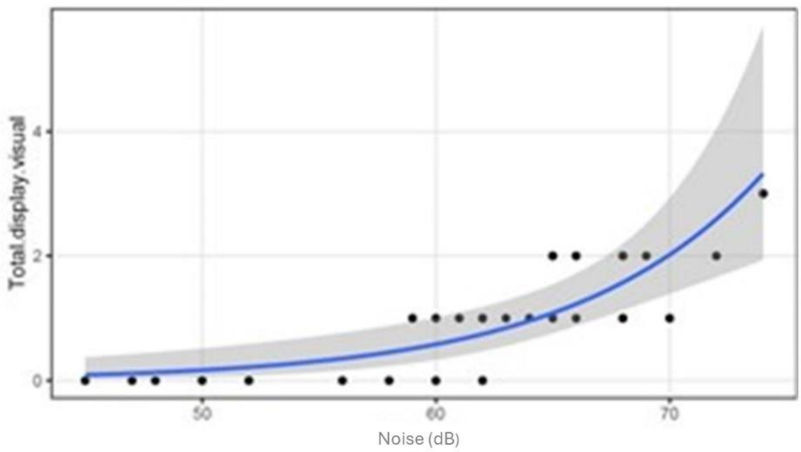

FIGURE 3. The correlation of noise to the probability of visual signals.

Previous research has often revealed a correlation between noise and frequency of visual signal display with a focus on random frog individuals or experiments, but population-level studies have not been conducted. For example, research by Moreno et al (2013) states that Eupsophus rosesus frogs increase the duration and frequency of acoustic signals and emit visual signals to overcome noisy surroundings. Another research conducted by Grafe & Tony (2017) on Staurois parvus individuals which conclusion is that continuous background noise even with height that is not always consistent can affect the multimodal signal expenditure of the individual. Beyond those researches, this study confirmed that noise also affects the population level where the prevalence of individual frogs that carry out visual signals is higher than the frog population in a quieter environment. Judging from the type of visual signal displayed, almost all types of visual signals show a uniform pattern where the prevalence of individuals using all these signals increases with increasing noise levels. This supports the hypothesis of visual signals as amplifiers of acoustic signals to enhance information in communication between individuals in noisy environments.

Correlation of conspecific density to the probability of visual signals

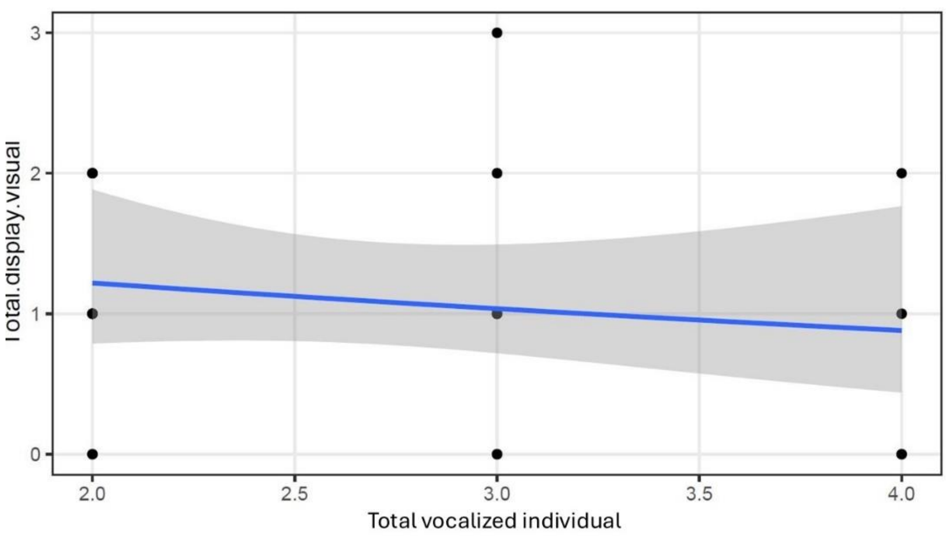

FIGURE 4. The correlation of conspecific density to the probability of visual signals.

Figure 4 shows decreasing visual signal percentage, which means conspecific density has no effect on visual signal expenditure in *L. borbonica* individuals. This study showed that high or low conspecific densities in a plot did not affect the number of visual signals displayed by *L. borbonica* individuals. Conspecific density can affect the output of visual signals as an alternative to communication if the main communication (acoustic) is not conveyed clearly. This is contrary to previous studies on conspecific individual density in vertebrates which suggest that background noise from similar individuals can pose problems in the correctness of signal detection and discrimination (Wollerman & Wiley, 2002b). This inverse or contradictory comparison is thought to be due to the distribution of L. borbonica, which prefers to communicate in quiet environments, therefore the more noisy (due to conspecific density), the fewer frogs found the fewer visual signals. In this case, the visual signal displayed is not so much suspected because the signal is not needed to clarify information because the density of conspecifics is not high and visual signals are not displayed in order to reduce intraspecific competition. Andreani et al., (2023) observed that Boana goiana individuals change acoustic and visual behavior in response to simulated arrival of conspecific frogs. The individual issues fewer advertising calls and more aggressive calls with the arrival of conspecifics individuals.

CONCLUSIONS

The density of *L. borbonica* is 4.8±1.4 individuals/50 m². There are 6 visual signal types detected in L. borbonica: arm lifting, face wiping, limb lifting, leg kicking, turning, and soundless vocal sac. There is a significant effect of natural noise on the prevalence of visual signals in *L. borbonica* in the Cisuren Rapids. There is no effect of conspecific sound density on the prevalence of visual signals in *L. borbonica* in the Cisuren Rapids.

AUTHOR CONTRIBUTIONS

RTI, MIN: project conception, methodology; RTI, MIN, VR: Data analyses; RTI: original manuscript draft; RTI, MIN, VR: manuscript review and editing.

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CONFLICTS OF INTEREST STATEMENT

There are no conflicts to declare.

DISCLOSURES AND ETHICS

As a requirement of publication author(s) have provided to the publisher signed confirmation of compliance with legal and ethical obligations including but not limited to the following: authorship and contributorship, conflicts of interest, privacy and confidentiality and (where applicable) protection of human and animal research subjects.

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