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Review Article

Function of Air Sac between *Symphalangus syndactylus* and *Hylobates klosii*: Comparative Study on Dynamics of Fundamental Frequency (F0) and Frequency of Formant (F0-Fmax) within Vocalization -

Dwi Atmoko Agung Nugroho*

Primatology Major, Bogor Agricultural University Indonesia

***Address for Correspondence:** Dwi Atmoko Agung Nugroho, Primatology Major, Bogor Agricultural University Indonesia, Jl. Lodaya II, No. 5, Bogor-16151 Indonesia, Tel: +62-251- 8313637/8324017; E-mail: mokonugroho28@gmail.com

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ABSTRACT

In the course of research on the function of air sac on vocalization, this study offers a comparative method between two species of non-human primate that have kinship closeness. The method adopted is to compare the dynamics of the fundamental frequency (F0) and the distance between the fundamental frequency to the frequency of formant maximum (F0-Fmax) vocals on the species *Symphalangus syndactylus* and species *Hylobates klosii* with the analysis of the sonogram using audio software Cool Edit Pro V2 in Blackman-Harris scale, descriptive statistics, and one way ANOVA by SPSS 17 software, graphical analysis with MS WORD 2010. The results of graphic analysis shows two things: First, the pitch of *S.syndactylus* more dynamic that is preceded by a low tone at the beginning and then riding on the pre-trill and first trill, decreased in the second trill, slightly up in the third trill, and dropped back on the fourth trill, again rising with the highest tone on the fifth trill. While the tone pattern (pitch) H.klosii tend to be more monotonous. Second, the vocal of *S.syndactylus* maximum resonating at the pre-trill and first trill while H.klosii maximum resonating at the sixth trill. Conclusions obtained is that graphical analysis of the fundamental frequency dynamics difference (F0) between *Symphalangus syndactylus* and Hylobates klosii can explain the function of *Symphalangus syndactylus's* air sac as a means of shaping the tone or song patterns. Graphical analysis of the difference in the dynamics of the distance between the fundamental frequency to the maximum formant frequency (F0-Fmax) between Symphalangus syndactylus and Hylobates klosii can explain the function of the *Symphalangus syndactylus's* air sac as a resonance production tool at the initial notes of a song.

INTRODUCTION

Research on the function of air sac on vocalization within *Symphalangus syndactylus* and Alouatta Seniculus has been done by de Boer [1]. The de Boer (2009) study was to find the effect of air sac on the vocalizations of both species by using the method of acyclic-tube modeling, and it found that air sac can only resonate at low frequencies below 2000 Hz.

Still in searching the function of air sac on vocalization, this study will offer a comparative analysis on the dynamic of fundamental frequency (F0) and the distance between the fundamental frequency to the maximum formant frequency (F0-Fmax) in vocalization both of *Symphalangus syndactylus* with close species such as *Hylobates klosii*. This comparative model is expected to be applicable for prospective research in order to explain the diversity of dialects in verbal species due to differences in anatomy and physiology of vocalization.

We hypotheses that the dynamics of fundamental frequency (F0) and the distance between the fundamental frequencies to the maximum formant frequency (F0-Fmax) in vocalization of *Symphalangus syndactylus* and *Hylobates klosii* have similarities because these two species are still close each other, but in another way they would have differences because each species has anatomical differences related to air sacs.

The study of the evolution of communication and vocalization in the gibbon family has been spearheaded by Thomas Geissmann [2]. In general, the function of vocalization in the species is to attract attention, defend territory, maintain spouse, and support the couple [3-5].

Vocalization is defined as the vibration of a membrane produced by air pressure flowing and enlarged in the vocal fold within the larynx. The air from the lungs passing through and enlarged by the vocal fold will produce a lot of frequency spectrum. The number of vibrations per unit time of the vocal fold wave having the largest amplitude is defined as the fundamental frequency (F0). The integral multiple of fundamental frequencies is called harmonics. The spectrum frequencies that have the greatest amplitude among the harmonics are called formants [6-10]. Individuals with higher levels of androgen will result in a higher F0-vocal [11]. Still associated with the acoustic function of the anatomy, the occurrence of vocalizations within these species is also supported by the vibration of the air sac, which the function of the air sac is still interesting for further investigation because each species has different anatomical of air sac, for example: the air sac of the *Symphalangus syndactylus* species is connected to the vocal fold within the larynx by the lateral ventricle while the air sac of Alouatta Seniculus species is located beneath the hyoid bone connected with the vocal fold within the larynx by the canal within the thyroid ligament [1].

METHOD

Subject

The subjects consisted of two groups of *Symphalangus syndactylus* and one group Hylobates klosii. One group of *Symphalangus syndactylus* consists of 1 male parent, 1 female parent, and 1 child. The *Hylobates klosii* group consists of 1 young male and 1 adult female.

Variables

Vocalizations (call) are divided into introduction, pre-trill and trill [2]. The fundamental frequency (F0) is the amount of vibration per unit time of the sound wave having the greatest amplitude. The distance between the fundamental frequency to the maximum formant frequency (F0-Fmax) is the difference between the fundamental frequency and harmonic spectrum frequencies that have the highest amplitude (decibels).

Place and time

The research place was Taman Safari Bogor-Indonesia held on Monday at 10:00 to 12:00 pm on 19 June 2017.

Procedures

The researcher stood beside the cage with a distance of 5 to 10 meters from the subject. The samples of the data were taken with Canon A2300 video camera in an "opportunistic way" and random manner at any time when there was a subject spontaneously vocalizing ad libitum (please see the video as suplementary data). Successful data samples taken with the net quality of 'noise' are from some 'call' of a male Symphalangus syndactylus because in the context of a duet it turns out that male vocals follow behind the female vocals so that only male vocals will be captured more clearly without any interruption of vowels female (please see the video). While the sample data 'call' *Hylobates klosii* taken from the subject of the female because only the subject of the female who did vocalization at the clock taking data. Samples of data taken with a Canon A2300 video camera from some 'call' a male *Symphalangus syndactylus* and a female *Hylobates klosii*

Figure 1: S.syndactylus vocal sample of one 'call'..

Figure 2: H.klosii vocal sample of one 'call'.

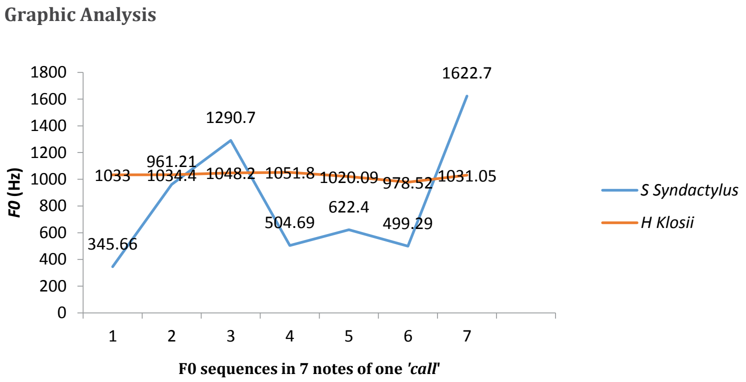

Figure 3: The call 'call' dynamics of F0 between S.syndactylus and H.klosii show that the S.syndactylus pitch pattern is more dynamic that begins with a low tone at the beginning and then rises in the pre-trill and first trill, down on the second trill, slightly up on the third trill, and back down on the fourth trill, back up with the highest tone on the fifth trill. While the tone pattern (pitch) H.klosii tend to be more monotonous or flat.

were converted to Wave format with Cool edit V2 audio software. One 'call' Symphalangus syndactylus males have 7 tone stages or (note) so that a single 'call' female Hylobates klosii consisting of more than 7 (note) must be cut to balance the analysis.

Vocal Acoustic Analysis

From the 7 stages of the tone then performed 3 steps of analysis include:

- Sonogram analysis using audio Cool Edit pro V2 software with Blackman-Harris scale.
- Statistical analysis of descriptive and one-way ANOVA by using SPSS 17 software
- Graphical analysis with MS WORD 2010

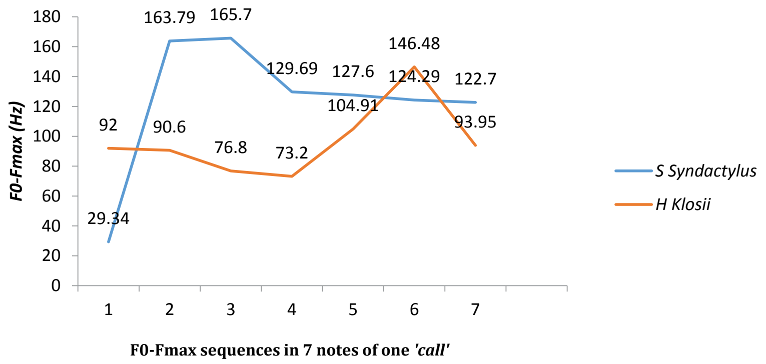

Figure 4: The 'call' dynamics in F0-Fmax between S.syndactylus and H.klosii show that the sound of the S.syndactylus vowel resonates maximally in the pre-trill and the first trill while the H.klosii vocal sound resonates maximally on the sixth trill.

Table 1: Acoustic analyzes on S.syndactylus vocal of one 'call'.

Notes	Name	Start	Finish	Duration	F0 (Hz)	Fmax (Hz)	dBmax	F0-Fmax
	Int	1:1.06	1:1.10	0:0.04	345.66	375	-08.892	29.34
	PT	1:1.10	3:1.01	1:0.07	961.21	1125	-12.98	163.79
	T1	3:1.01	3:1.05	0:0.04	1290.70	1125	-22.50	165.70
	T2	3:1.05	3:1.09	0:0.04	504.69	375	-26.46	129.69
	T3	3:1.09	3:1.14	0:0.05	622.40	750	-17.67	127.60
	T4	3:1.14	4:1.04	0:0.06	499.29	375	-24.10	124.29
	T5	4:1.04	4:1.11	0:0.07	1622.70	1500	-33.72	122.70

Index: Int (Introduction), PT (Pre-Trill), T (Trill)

Table 2: Acoustic analyzes on H. klosii vocal of one 'call'.

Notes	Name	Start	Finish	Duration	F0 (Hz)	Fmax (Hz)	dBmax	F0-Fmax
	Int	1:1.00	3:1.04	2:0.04	1033.00	1125	-08.980	92.00
	T1	3:1.04	4:1.08	1:0.04	1034.40	1125	-09.103	90.60
	T2	4:1.08	5:1.12	1:0.04	1048.20	1125	-09.137	76.80
	T3	5:1.12	6:1.12	1:0.00	1051.80	1125	-13.36	73.20
	T4	6:1.12	7:1.08	0:0.12	1020.09	1125	-18.18	104.91
	T5	7:1.08	8:1.04	0:0.12	978.52	1125	-09.43	146.48
	T6	8:1.04	9:1.00	0:0.12	1031.05	1125	-15.36	93.95

Index: Int (Introduction), T (Trill)

RESULT

Statistical analysis

The fundamental frequency (F0): Analysis of primary data (see table 1 and 2) shows that in general the mean F0 S.syndactylus = 835.24 Hz (SD = ± 474.43, variances = 225086.77 at n = 7). Mean F0 H.klosii = 1028.1514 Hz, (SD=±24.3599, variances = 593.4034 at n = 7). Comparative analysis of F0 with one-way ANOVA showed that the mean F0 S.syndactylus and H.klosii did not differ significantly (1.12) = 1.154 with p > 0.05.

The distance between fundamental frequency to maximum formant frequency (F0-Fmax): Analysis of primary data (see table 1 and 2) (figure 1-4) shows that in general the average F0-Fmax S.syndactylus = 123.30 Hz (SD = ± 45.32, variances = 2054.39 at n = 7). Mean of F0-Fmax H.klosii = 96.8486 Hz, SD = ± 24.36, variances = 593.40 at n = 7). Comparative analysis of F0 with one-way ANOVA showed that the mean F0-Fmax S.syndactylus and H.klosii did not differ significantly (1.12) = 1.85 with *p* > 0.05.

DISCUSSION

De Boer's [1] founding that air sac can only resonate at low frequencies below 2000 Hz still confirmed here. The results of this study show that statistically, vocalizations in *Symphalangus syndactylus* and *Hylobates klosii* still have similarities (not significantly different) in terms of the fundamental frequency dynamics (F0) and the distance between the fundamental frequency to the maximum formant frequency (F0-Fmax) so that the first hypothesis be accepted. This resemblance of vowel behavior can certainly be used to support speciation in addition to supporting the theory that behavior is a genetic product or an inherited trait evolutionarily [2].

However, graphical analysis shows that there are differences in pitch and resonance patterns in both species so that the second hypothesis is also accepted. In general, the difference in tone patterns may represent the difference in lyrnx flexibility in both species but can typically represent the physiological functions of the *Symphalangus syndactylus*'s air sac as a tone-patterning instrument or better known as a song and this pattern is not likely to be possessed by *Hylobates klosii* which has a smaller size of air sac [12,13]. The physiological functions of other Symphalangus syndactylus's air sac may also be described as resonance production tools at the beginning of the song, which is also not found in *Hylobates klosii.*

CONCLUSION

Graphical analysis of the fundamental frequency dynamics difference (F0) between *Symphalangus syndactylus* and *Hylobates klosii* can explain the function of *Symphalangus syndactylus* airsac as a means of shaping the tone or song patterns. Graphical analysis of the difference in the dynamics of the distance between the fundamental frequency to the maximum formant frequency (F0-Fmax) between *Symphalangus syndactylus* and *Hylobates klosii* can explain the function of the *symphalangus syndactylus's* air sac as a resonance production tool at the initial notes of a song. This study recommends prospective studies with the same themes and objectives but with different sound analysis software as confirmation of the effect of the difference in standardization of the measuring device and the size of scale used.

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