Bioacoustic Characteristics of Whistle Sounds and behaviour of male Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) in Indonesia

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Abstract- Bioacoustics is the science that combines biology and acoustics and refers to the production of sound, dispersion and reception by/to animals and humans. This study used acoustic and behavioral observations of dolphins to see the different patterns of sound, and describe behavior physiotherapy pool at Safari Park Indonesia, Cisarua Bogor. Power Spectral Density (PSD), the frequency range of the whistle sound different from one another. The highest intensity values that are at the sound of the whistle 3 after eat show pool with an intensity value of 25.57 dB at a frequency of 14470 Hz. Test result F before eating physiotherapy pool have in common (Homogeneous) contained in the relationship between the time 500 to 600 with the results of the whistle 1, 2, 3, and 4 are Reject Ho (Fhit> F table). Position of dolphins in a pool physiotherapy more dominant and often located in the bottom of the pool.

Index Terms- Bioacoustic, Male bottlenose dolphins (Tursiops aduncus), Frequency, Intensity

I. Introduction

In the world of fisheries, acoustic passive methods are applied to monitor marine mammals, and the sea biota as on [1]. Signals obtained from recording sound marine mammals are very weak , need calls amplification and it is very difficult to determine the direction of arrival of each sound. Passive sound might be derived from animals target [2]. A method of acoustic passive also used in the field of military service for the development of security system involves the sound recording produced by diving [3]. Hearing of marine mammals is measured in the living subject with the use of audiometer or electro physiological techniques [4]. . Characteristic of hearing can be predicted based on the frequency of produced sounds, it is better to have measured responses of behavior in trained animals [5] and [6].

Currently little is known about the bottlenose dolphin sound type referred to as yelping (burst), which is characteristized by spectral , temporal , and amplitude as a shrill sound pulse whistle type very few researchers have explored. As for early description in literature, most of it is only qualitative , that reflects subjective interpretation and classification hearing in humans [7]. The sound of a whistle generally used for echolocation , while the sound of a whistle yelping (burst) plays a major role in communication [1]. Whistles that continues unlimited, giving signals frequency [8] , with various wide emissions of 800 Hz and 28.5 KHz [9] often there are harmonic components [8]. Dolphin hearing ranges from about 50 Hz-150 KHz , with somevariation among species [9]. Because the science of acoustics is growing rapidly for dolphins , researchers formerly had been exercising records and analysis vocalization [10]. This study aims to analyse and distinguish characteristics of the whistle sound of a male bottlenosebottle nose (*Tursiops aduncus*) in the pool physiotherapy , by using passive recordings and and behavioral observations.

II. Tools and Materials

Currently little is known about the bottlenose dolphin sound type referred to as yelping (burst) , which is characteristized by spectral , temporal , and amplitude as a shrill sound pulse whistle type very few researchers have explored. As for early description in literature, most of it is only qualitative , that reflects subjective interpretation and classification hearing in [7]. The sound of a whistle generally used for echolocation , while the sound of a whistle yelping (burst) plays a major role in communication [1]. Whistles that continues unlimited , giving signals frequency [8] , with various wide emissions of 800 Hz and 28.5 KHz [9], often there are harmonic components [8] Dolphin hearing ranges from about 50 Hz-150 KHz , with somevariation among species [10] Because the science of acoustics is growing rapidly for dolphins , researchers formerly had been exercising records and analysis vocalization [10]**.** This study aims to analyse and distinguish characteristics of the whistle sound of a male bottlenosebottle nose (*Tursiops aduncus*) in the pool quarantine , by using passive recordings and and behavioral observations.

Tools and material used in the research methodology include: hidrofon SQ3 (instrument passive acoustic), a thermometer hg to measure the temperature of water; refractometer for measuring water salinity, . dolphin EAR 100 hydrophones with serial number DE989505, camera underwater gopro hero 3 + serves to record the movement of dolphins visually while in the pool. Software Matlab and Wavelab were used to process the observations collected from dolphins in the pool named quarantine. Data were processed and filtered using Wavelab software to obtain the sound to be analyzed by means of power spectral density technique through Matlab routines. Hydrophone is usually in the form of a piezo-electric slab, and a standardization of hydrophone for purposes of biocoustic was issued by Bioacoustic Inc. Hydrophone is usually in the form of a piezo-electric slab, and Standardization of Hydrophone for purposes of bioacoustic recordings was issued by Bioacoustic Inc. Hydrophone limited the range of frequencies recorded to the frequency of sounds that can be heard normally by using earphones for humans [11]. Software Wavelab provides functions for recording sound directly from dolphin ear, so the lowest frequencies that can be detected, will be lower than several Hz, and the upper limit of a frequency that can be detected can reach more than 78 22 kHz.

III. Recorded Whistles

Whistles were extracted from underwater video and sound recordings made between Mei and Juni 2015 with video cameras (Gopro Hero 3+) and a SQR 3 hydrophone, flat to 22 kHz with a –192 dB re 1 µPa. Whistles were assigned to specific individuals when a dolphin was alone in the camera/hydrophone vicinity, in sole proximity (< 1 m) of the camera/hydrophone, or showed simultaneous bubble emissions correlated with a whistle. Although amplitude can be variable in dolphin vocalizations, individuals more than 5 m away from the recording equipment never emitted whistles as loud as dolphins within 1 m. If a group of dolphins was present, intensity of the whistle was only used to determine the whistling individual when one dolphin was close to the hydrophone (< 1 m) and the rest of the group was further away (≥ 5 m). Some previous studies have relied on only bubble streams to identify the vocalizing individuals e.g.[12],[13];[14]; see also [15]. However, our unique underwater viewing allowed us to note not only bubble streams, but also the directional orientation and proximity of individuals to the recording equipment and the lack of other dolphins at the park of safari, Cisarua Bogor in Indonesia. Whistles were digitized from audio recordings using *Raven Pro 1.5* software (Cornell University, Ithaca, NY, USA) at 44.1 kHz sampling rate (Whistle 1, 2, 3, and 4). Data Analysis with Test F, All statistical tests were run with *SPSS 14.0* software.

IV. Fourier Transform

The basis to study the characteristic in frequency of a signal is the Fourier transformation by [16]**.** Fast Fourier transform (FFT) is an algorithm to count Fourier transform. A signal in the time domain, nominally, x (t) ca be transformed in a signal in the frequency domain , nominally X(f), applying the FFT methods as shown in the following equations.

$$X(f) = \int_{-\infty}^{\infty} x(t) \bullet e^{-2\pi ft} dt. \qquad (1)$$

$$x(t) = \int_{-\infty}^{\infty} X(f) \bullet e^{-2\pi ft} df. \qquad (2)$$

Where t is time, f is the frequency. x is the notation of a signal in the time domain and X is the notation for signals in the frequency domain. Equation (3) is called the Fourier transform of x (t), while equation (4) is called the inverse Fourier transform of X (f).

V. Power Spectral Density

The frequency of a wave is naturally determined by the frequency source. The rate of the wave through a medium is determined by the properties of the medium. Once the frequency (f) and speed of sound (v) of the wave has been given, then the wavelength (λ) has been set. With the relationship f = 1 / T can be obtained equation (3):

$$\lambda = \frac{v}{f} \qquad (3)$$

Because the study used the speed of sound in the water medium, ie seawater. Then the speed of sound in air is denoted by (v) can be changed with the speed of sound in water that is denoted by (C), so that equation (4) :

$$\lambda = \frac{C}{f} \qquad (4)$$

Power spectral density (PSD) definition as the magnitude of the power per intervals frequency , in the form of mathematics [16] :

$$\text{PSD} = \frac{|Xn|^2}{f} \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \left(\frac{(Amplitudo)^2}{Hz}\right) \qquad (5)$$

Calculation of psd in matlab uses the Welch method [17] , namely looking for DFT (based on FFT algorithms) , then squaring the value of the magnitude .

VI. Result and Discussion

Sound of mammals (dolphins) analyzed in this research is the noise that derived from the skull of dolphins. According to [18], sound is very important to understand the behavior while communicating of several kinds of fish and according to [19] mammals can issue various amplitude sounds for communicating in exchange information. Analysis of their sound can lead to deepen the knowledge of the produced sound while mammals are eating, moving, escaping from predator, and also can contribute to know more about their reproduction (sexuality and phase enlargement) [10]. From the recorded sound, dolphins bottle nose (*Tursiops aduncus*) have three types of different tones. The result of the observations are summarized in Table 1.

Table 1. Time, Minimum intensity, Maximum intensity, Mean Frequency, and Range intensity

Whistle	Time (ms)	Min Intensity (dB)	Max Intensity (dB)	Mean Frequency (Hz)	Range Intensity
	100	23.29	23.8	14470.31	0.51
	200	23.35	24.17	10163.67	0.82
	300	23.29	23.84	12316.99	0.55
1	400	23.2	23.88	14470.31	0.68
	500	23	24.04	16623.63	1.04
	600	23.39	23.75	18776.95	0.36
	700	23.34	24.03	20930.27	0.69
	100	23.33	24.14	8010.35	0.81
	200	23.18	24.02	10163.67	0.84
	300	22.67	23.9	12316.99	1.23
2	400	23.29	23.79	14470.31	0.5
	500	23.93	24.05	16623.63	0.12
	600	23.23	23.85	18776.95	0.62
	700	23.15	23.67	2090.27	0.52
	100	23.3	23.83	8503.03	0.53
	200	23.13	24.12	10094.77	0.99
	300	23.02	24.16	11893.22	1.14
3	400	22.91	24	14470.31	1.09
	500	23.13	23.62	16623.63	0.49
	600	23.02	23.7	18776.95	0.68
	700	22.9	23.66	20930.27	0.76
	100	23.62	24.11	8010.35	0.49
	200	23.31	23.91	10163.67	0.6
	300	23.13	23.82	12316.99	0.69
4	400	23.29	24.53	14470.31	1.24
	500	23.24	24.09	16623.63	0.85
	600	23.11	23.75	18776.95	0.64
	700	23.19	23.82	20930.27	0.63

Table 2 F Test Whistle at physiotherapy pool

NO	Time (ms)	Whistle Sounds male Indo-Pacific bottlenose dolphins			
		Peluit 1	Peluit 2	Peluit 3	Peluit 4
1	100 with200	-	*	-	*
2	200 with 300	-	*	-	*
3	300 with 400	*	*	*	-
4	400 with500	*	-	*	-
5	500 with 600	*	*	*	*
6	600 with 700	-	-	*	*

-) Not significant effect (Accept Ho) (Fhit<Ftabel)
*) Significant (Reject Ho) (Fhit>Ftabel)

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Table 1 showed time, minimum intensity, maximum intensity, mean frequency, and range intensity. The intensity range that is currently on the whistle 4 at 400 ms, and the low intensity range is on a whistle 2 at a time of 500 ms. F test based on Table 2 the sound of the whistle 1 at 100 to 200, 200 to 300 ms, 300 to 400 ms, 400 to 500 ms has a value of P> 0.001, while the sound of the whistle of 500 to 600 ms, 600 to 700 have a value of P <0.001 , 2 whistle sound at the time of 100 to 200, 200 to 300 ms, 300 ms to 400, 400 to 500 ms, and 600 to 700 ms has a value of P> 0.001, while the sound of the whistle of 500 to 600 ms has a value of P <0.001. 3 whistle sound at the time of 200 to 300 ms, 300 ms to 400, 500 to 600 ms, and 600 to 700 ms has a value of P> 0.001, while the sound of the whistle 100 to 200, 500 to 600 ms has a value of P <0.001. 4 whistle sounds at 100 to 200, 200 to 300 ms, 300 ms to 400, 400 to 500, 500 to 600 ms, and 600 to 700 ms has a value of P <0.001. Test results F have in common (Homogeneous) contained in the relationship between the time 500 to 600 with the results of the whistle 1, 2, 3, and 4 are Reject Ho (Fhit> F table), while the sound of a whistle with a time of 100 to 200, 200 to 300, 300 400, 400 to 500, and 600 to 700 ms is not uniform by seeing patterns and relationships (F Test).

VII. Characteristic of Dolphin Sound

Whistle sound is the sound produced dolphins from melon (the sound source). The sound produced by the dolphin which is usually referred to as a marker signal, and the sound of the whistle is also used to maintain communications between individual dolphins [20]. Whistle sounds produced by dolphins can reach 17.04 KHz [1]. The original spectrum by analyzing the pattern of MATLAB to see the number of existing spectrum whistle sounds. Whistle sound used is 4-5 sounds in the range within ± 5 minutes. Original sound of the whistle an original spectrum that has not been done filter. Original Sound whistle at physiotherapy pool can be seen in Figure 1,2,3,4,

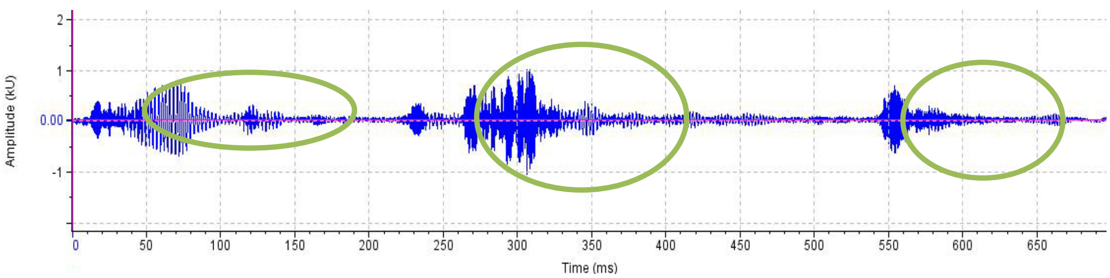
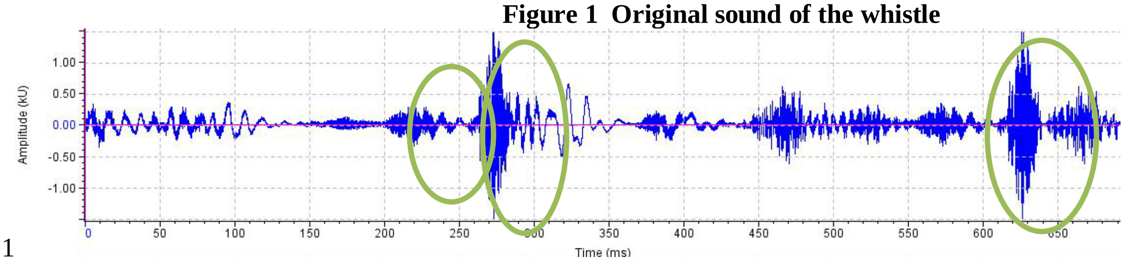


Figure 1 Original sound of the whistle



1

Figure 2 Original sound of the whistle 2

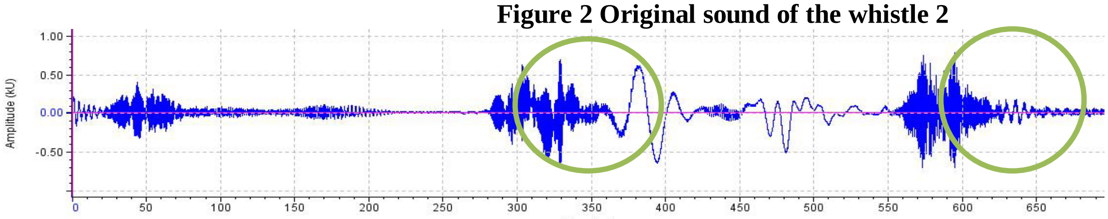


Figure 3 Original sound of the whistle 3

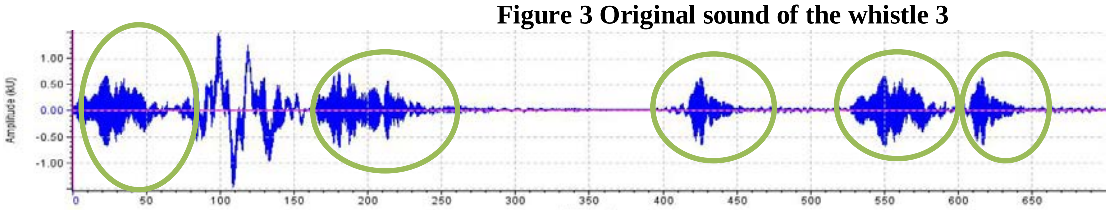


Figure 4 Original sound of the whistle 4

Figure 1has obtained the original sound 3 sound patterns that are at a time of 50-100 ms, 240-350 ms and 540-600 ms. Figure 2 has three very strong pattern of the spectrum which is located at 200-230 ms, 240-300 ms and 500-600 ms. Figure 3 also has a third voice pattern of how during 10-80 ms, 300-350 ms and 550-650 ms, whereas in figure 4 have a sound pattern more than the sound of 1, 2 , 3, the whistle 4 has 5 sound patterns with time is 0-50 ms, 150-200 ms, 400-450 ms, 500-550 ms, and the last 600-650. Results of original whistle sound generated at a pool physiotherapy and show the treatment before and after meals have the same maximum time range is 700 ms, has a number of different patterns and have a different pattern each time. According to [21], [24], [25] mean duration of the sound of the whistle on common bottlenose dolphin that was dipenangkaran / pool which is about 600 ms. Results of this spectrum shows the original time range sound made by previous research have a range of almost the same time with a difference of 100 ms difference.

Power Spectral Density (PSD) function to equalize the number of rows and columns of data matrix m-file from the sound recording process. Power spectral density is a useful concept to determine the optimum frequency band of the signal transmission system. PSD is a variation of the power (energy) as a function of frequency spectrum in the form of density estimated using FFT, PSD method is one of the modern spectral estimation technique proposed during this decade [22] Figure 5 shows the four whistle sound generated by the value of Power Spectral Density (PSD), which is found in the highest with 24.30 dB are shown in black color on 4 when the whistle sounds before eating physiotherapy pool (indicated by black circles). The highest intensity value lies in the frequency interval of 14100 Hz, while the lowest value that is located on the second whistle with a frequency of 8200 Hz with a value of Power Spectral Density (PSD) 22.70 dB as indicated by the blue line.

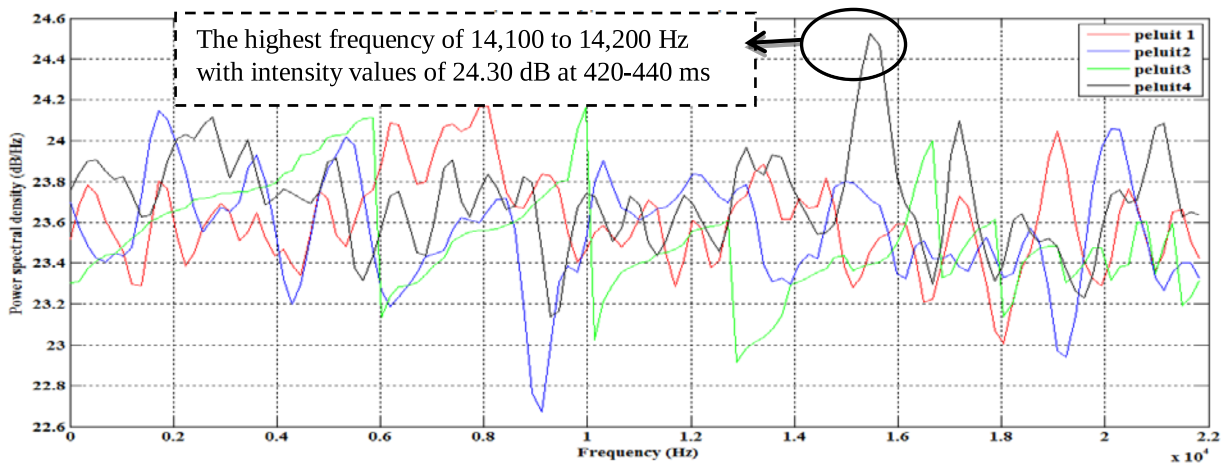


Figure 5 Power Spectral Density whistle 1-4

From the results obtained can be identified as the whistle sounds emanating from dolphins by calculating or viewing range interval whistle sound itself [20]. Highest intensity on a whistle 4 can also be affected by the position with the position of the dolphin is horizontal, because according to [23], movement in the vertical position will probably affect the magnitude of the sound and the inconsistency of the sound emitted by the dolphins using conservation methods energy obtained by dolphins, and will require a lot of energy to expend greater voice intensity value.

VIII. BEHAVIVIOUR OF MALE INDO-PACIFIC BOTTLENOSE DOLPHINS

Behavior of dolphins taken using recording underwater and above the water surface (GoPro Hero 3+). Dolphin behavior include position where dolphins male bottle nose while in captivity pool physiotherapy and show. Image position and behavior of dolphins is obtained by adjusting the sampling sound (Wavelab), position and behavior of dolphins at physiotherapy pool can be seen in figure 6.

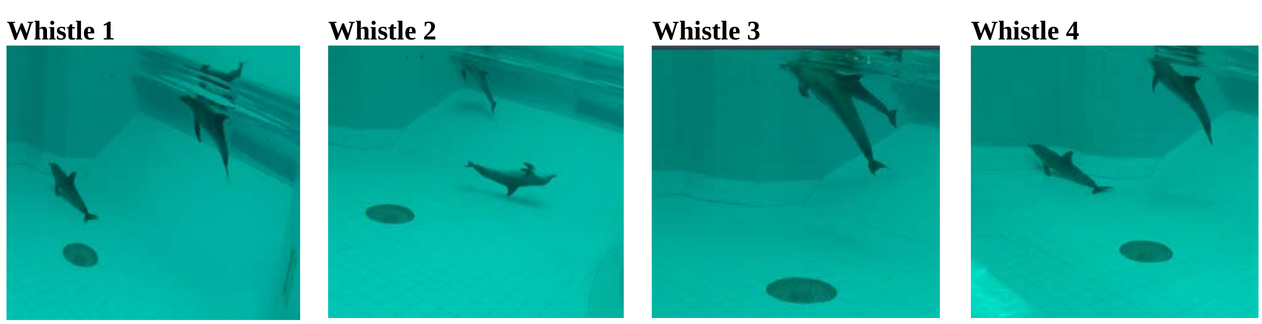


Figure 6 position and behavior of male dolphins physiotherapy pool

Figure 6 shows the behavior of dolphins at physiotherapy pool with the sound of the whistle 3 physiotherapy seen dolphins are in the same pool with the surface, while the whistle 1, 2, and 4 look the dolphins on the surface. This explains the position of dolphins in a pool physiotherapy more dominant and often located in the bottom of the pool (less doing the movement). The position of the movement and the ecology of common bottlenose dolphin whistle to sound produced will affect the frequency generated by dolphins (Papale et al. 2014).

IX. Conclusion

Male Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) in Cisarua, Bogor Indonesia has power Spectral Density (PSD) and frequency range of the whistle sound different from one another. The highest intensity value is the sound of a whistle 4 with intensity values 23.40 dB at a frequency 14100-14200 Hz. Position of dolphins in a pool physiotherapy more dominant and often located in the bottom of the pool.

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