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Indo-Pacific Bottlenose Dolphins (*Tursiops aduncus*) Whistle Sound by Denoising Spectra with Discrete Wavelet Transform (DWT)

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Abstract

Bottlenose dolphins (*Tursiops aduncus*) use whistles to communicate with their conspecifics and maintain group cohesion. We recorded 8 whistles of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) in the Safari Park, Cisarua Bogor, Indonesia between 10th - 15th May 2015. Dicrete Wavelet Transform (DWT) using Haar wavelet method for analysis whistle sound of Indo-Pasific Bottle Nose Dolphins.Discrete Wavelet Transform (DWT) Showed difference between the treatment before and after meal at whistle sound. DWT in Wavelet have Haar wavelet method produced highest value of Power Spectral Density Level (PSDL) is 61 dB re 1μPa^2 / Hz, and lowest value is -80 dB re 1μPa^2 / Hz. Interval whistle have a equation y= -8.6x+ 97 , R^2= 0.3658 (36%) in show pool, before meal treatment. While in show pool, after meal treatment have y= x+55.5, R^2= 0.0758 (8%).Before meal treatment in ANOVA have Y = 22.5045 + 0.000097 X, and have percentage of R^2 value is 1 %, percentage of Significance F value is 63%. ANOVA in Equation of whistle sound after meal have Y = 24.2824 + -0.0000434 X have percentage of significance F value is 81%.

Keywords: Bottlenose dolphins; whistle sounds; Dicrete Wavelet Transform; Power Spectral Density Level

Abbreviations: DWT: Discrete Wavelet Transform; PSDL: Power Spectral Density Level; FFT: Fast Fourier Transforms; WT: Wavelet Transform; STFT: short time Fourier Transform

Introduction

In numerical functional and analysis, a method of Discrete Wavelet Transform (DWT) is any wavelet transform in wavelet method for which the wavelets are discretely sampled. As with other wavelet transforms, key advantage has over of Fast Fourier Transforms (FFT) is temporal resolution: it captures both frequency [1].

Bottle nose dolphins including mammals that have good hearing sensitivity. It is caused by a network system senses of hearing has been well. Dolphins can hearing of sounds with frequencies range 1-150 kHz [2]. High sensitivity is indispensable for echolocation. Echolocation is the ability to sense through sound and hearing. This activity occurs in two steps, the first dolphin issued Clicks high frequency (120 kHz), and then projected through the front of the head area (melon) into the surrounding aqueous medium. When Clicks of an object, will form an echo or sound waves to be received by dolphins and processed into information about the location or type of object [3](Figure 1).

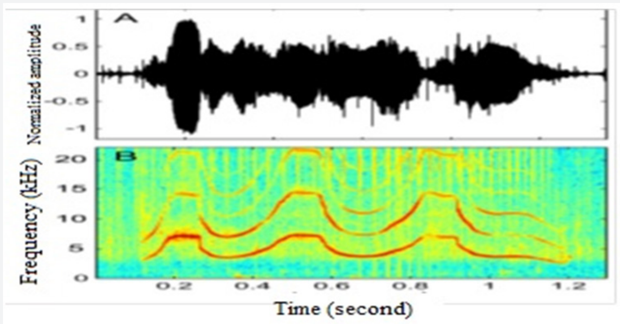

Figure 1: Dolphin whistle sound. (A) Waveform of whistle and (B) Whistle sound spectrograms display the frequency in which there is still noise [6].

DWT in Wavelet have Haar wavelet method and has an essential shortcoming: it is not continuous. In the points of discontinuity the derivatives do not exist, therefore it is not possible to apply haar wavelet directly for solving differential of equations. Haar wavelet family for t ∈ [0, 1] is defined [4]:

$$h_i(t) = \begin{cases} 1 \quad For & t \in \left[\frac{k}{m}, \frac{k+0.5}{m}\right) \\ 1 \quad For & t \in \left[\frac{k}{m}, \frac{k+0.5}{m}\right), \frac{k+1}{m} \\ 0 \text{ elsewhere} \end{cases}$$

Haar wavelet family t ∈[0, 1] have m Integer is = 2*j*(*j* = 0, 1, . . . , J) indicates level of the wavelet method is k = 0, 1, . . . , m − 1 is translation of parameter. Maximum level of resolution is J. The index i in (1) is calculated according with formula i = m + k + 1; in the case of minimal values is m = 1, k = 0 we have i = 2, max value i is i = 2M = 2^{j+1}. It is assumed that value to i = 1 corresponds to the scaling function for which $h_1 \equiv 1$ in [0, 1] and vanishes elsewhere. Let us define the collocation points tl = (l − 0.5)/(2M), (l = 1, 2, . . . , 2M) and discretise the Haar function hi(t); in this way we get the coefficient matrix H(i, l) = $(h_i(t_l))$, which has the dimension 2M × 2M. Operational next matrix of integration P, which is a 2M square matrix, is definition in equation [4]:

$$(PH) \int_0^{t_l} hi(t)dt. \quad (2)$$

Elements of the matrix H and P can be evaluated according to (1) and (2).For instance, if M = 2 we find the result is [4]:

$$H_4 = \begin{pmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & 0 & 0 \\ 1 & 0 & 1 & -1 \end{pmatrix} \quad P_4 = \frac{1}{16}\begin{pmatrix} 8 & -4 & -2 & -2 \\ 4 & 0 & -2 & 2 \\ 1 & 1 & 0 & 0 \\ 1 & -1 & 0 & 0 \end{pmatrix} \quad (3)$$

Whistle sound of dolphins is generally used for echolocation, and whistle also serves as a major role in communication between individuals and between groups [2,3]. Continuous whistle sound, signaling frequency [2], with a wide beam width of 800 Hz and 28.5 kHz [5] often has a harmonic component [5]. A dolphin starts the interaction with signal, with information, in the length of a particular frequency. Then signal sources depend on the source of the hearing and will cause a reaction to sound. Hearing in dolphins ranges from about 50 Hz-150 kHz, with additional variations among species [6].

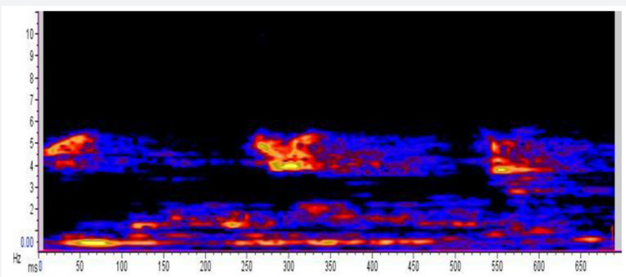

Figure 2: Spectrum of sound click male dolphins (*Tursiops aduncus*) [15].

Examples of spectrograms of whistle that there are noise or noise in it [7] can be seen in Figure 1, and click sound of dolphins can be seen in (Figure 2). Previous research by looking at whistling sound vocalizations of dolphins and a clicking sound is [8-10] bioacoustic research about stidulatory ever done with object Guppy fish [11-14]. The vocalisation characteristics described above have been found to vary among populations, possibly due to habitat differences, ambient noise, sympatry with other dolphin species, etc. In this article, the whistle characteristics of Indo-Pacific bottlenose dolphins were measured in captive of safari park, Cisarua, Indonesia. Data analysis in this research was done with MATLAB, Raven Pro 1.5, and Wavelab 6 software with haar wavelab method in signal processing using MATLAB software.

Methods

Data Collection

Data were collected in safari park, Cisarua Bogor, Indonesia from 10th to 15th May 2015. Acoustic instrument for collecting data was a hydrophone of type SQ3 with a built-in preamplifier, sensivity of- 163.9dB re V/μPa, and frequency response of 0 Hz - 35 kHz (±3 dB). SQ 3 recorders were used with Wave lab 6 Software, and the data stored as 16-bit WAV files. During recordings, the hydrophone was placed in show pool at safari park at a depth 0.5 m below the surface of the water. In the show pool there were two male dolphins which were used as the object of research. The dolphins had two tails of the same size, without a given name or tagging. The dolphins had a length of 2.1 meters, weighing 212 kg, and age of 11 years (dolphin is classified as an adult). The treatments given in this study were before and after meals. Figure of hyrophone and Set of sound recorders is shown in (Figure 3), and Sketch of experimental research showed in (Figure 4).

Figure 3: Set of sound recorders, (a) Hydrophone, (b) Headphone, (c) Power supply / battery, and (d) laptop for data logging and data processing.

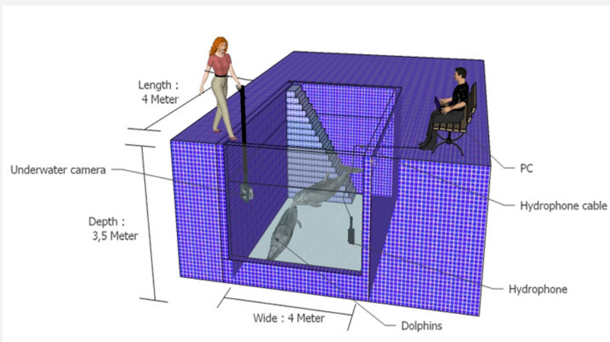

Figure 4: Sketch of experimental research of dolphins in show pool.

Data Analysis

Acoustic analysis focussed on the identification and description of whistles sound by bottlenose dolphins

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(*Tursiops aduncus*) in Safari Park, Cisarua, Indonesia. Denoised signal, Relationship Power Spectral Density Level (PSDL) and Time Duration, Haar wavelet 1 D (DWT Wavelet Tree) and approximation at level 5 presented in the results were generated in Matlab R2010a (The MathWorks Inc.), by Fast Fourier Transform(FFT) of the calibrated pressure time series, using Hamming windows of 2048 samples and 50% overlap. Spectrogram of a potential biphonic whistle was done. Sampling frequency=44 kHz, NFFT=2048, Hamming window, 50% overlap processing with Raven Pro 1.5 software of bioacoustics. Statistical analysis ANOVA method was used and has an interval of whistle from dolphin use SPSS Statistics 17.0.

Result and Discussion

Discrete Wavelet Transform (DWT)

While this paper aims to describe whistle sound recorded in captive, the dolphins have trained for behaviour in show pool. The pattern seen in the sound before meal has three patterns of sound that is at 50-190 ms, 250-500 ms and 550-620 ms respectively. This suggests the different sound patterns within a specific time range produced by dolphins with maximum time is 650 ms (Figure 5). Sound pattern of the whistle after meal has 4 times the range 0-140 ms, 160-240 ms, 250-400 ms and 470-640 ms. This shows the difference in the number of patterns of sound produced by the dolphin with their treatment before and after eating (Figure 6), and the result is almost the same as the previous study [1,8,15].

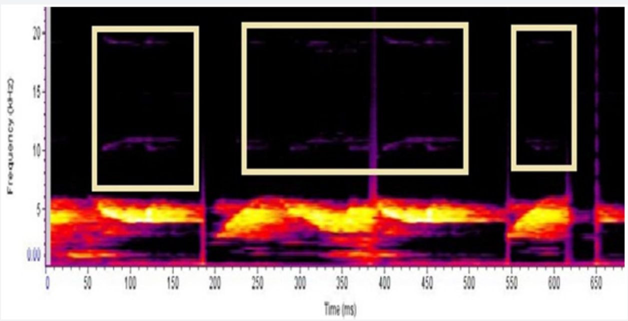

Figure 5: Spectrogram before meal of a potential biphonic whistle. Sampling frequency=44 kHz, NFFT=2048, Hamming window, 50% overlap.

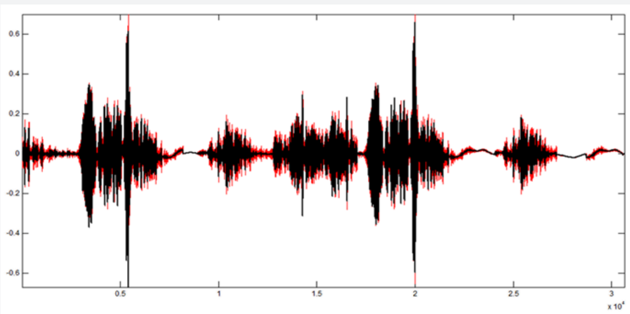

Figure 6: Denoised signal of whistle sound before meal (Red: Original Signal and Black: Denoised Signal).

Wavelet Transform (WT) is a technique for analyzing a signal. It was developed as an alternative to the short time Fourier Transform (STFT), an Fourier Transform (FT) to overcome problems related to its frequency and time resolution properties. More specifically, unlike the STFT that provides uniform time resolution for all frequencies, the DWT provides high time resolution and low frequency resolution for high frequencies and high frequency resolution and low time resolution for low frequencies. In that respect it is similar to the human ear which exhibits similar time-frequency resolution characteristics.

Relationship Power Spectral Density Level (PSDL) and Time Duration before, after meal of whistle sound have differences. Power Spectral Density Level (PSDL) initial value is 39 dB re 1μPa^2 / Hz, and the final value is at 130 ms, with the blue line shown is the result of original and red was modified with an algorithm which is owned by the Haar wavelet. Highest value of Power Spectral Density Level (PSDL) is 60 dB re 1μPa^2 / Hz, and lower value is -83 dB re 1μPa^2 / Hz (Figure 7). Power Spectral Density Level (PSDL) initial value is 40 dB re 1μPa^2 / Hz, and the final value is at 130 ms (same with treatment before meal), with the blue line shown is the result of original and red was modified with an algorithm which is owned by the Haar wavelet.

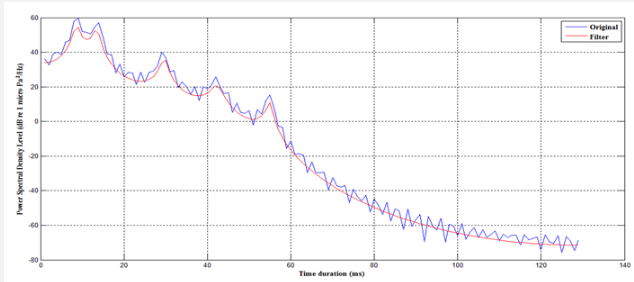

Figure 7: Relationship PSDL and Time Duration before meal of whistle sound (Original and filter).

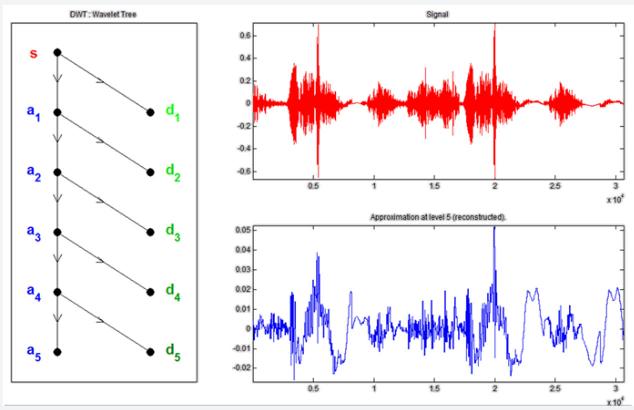

Figure 8: Haar wavelet 1 D (DWT Wavelet Tree) and approximation at level 5.

Highest value of Power Spectral Density Level (PSDL) is 61 dB re 1μPa^2 / Hz, and lower value is -80 dB re 1μPa^2 / Hz (Figure 8). This clearly shows whistle sound before and after meals has a value of Power Spectral Density Level (PSDL) different at

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highest and lowest. Values obtained more noise in treatment after a meal that is in the image 11 shown in black. Complex of Discrete Wavelets Transform (DWT) [16,17] may provide similar benefits, but we have not yet explored them thoroughly in the context of mass spectrometry data. An orthogonal (decimated) discrete wavelet transform (DWT) was used to study SELDI data derived from the serum of prostate cancer patients according to Qu Y, et al. [18-21].

Results of statistical processing

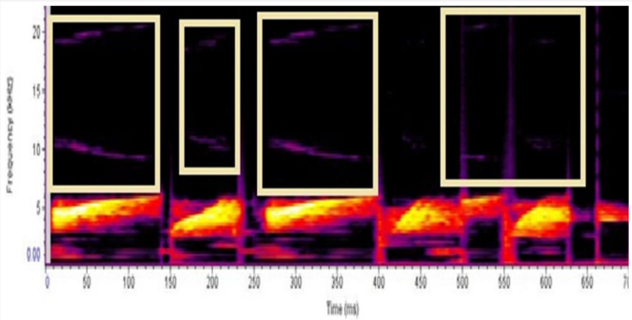

Figure 9: Spectrogram after meal of a potential biphonic whistle. Sampling frequency=44 kHz, NFFT=2048, Hamming window, 50% overlap.

In the results of statistical processing, the highest whistle interval value is 100 ms (red line) before meals treatment, and lowest whistle interval value is 52 ms (Black line) after meal treatment. Equation y= -8.6x + 97, R2= 0.3658 (36%) in show pool, before meal treatment. While in show pool, after meal treatment have y= x+55.5, R^2= 0.0758 (8%). From linear regression results obtained, it shows that the value of R^2 in treatment before meal has a greater percentage than in the time after meal (Figure 9). Interval whistle affect the value of noised generated [21], because the smaller the value noise obtained, the greater the value of the interval whistle (Figure 10).

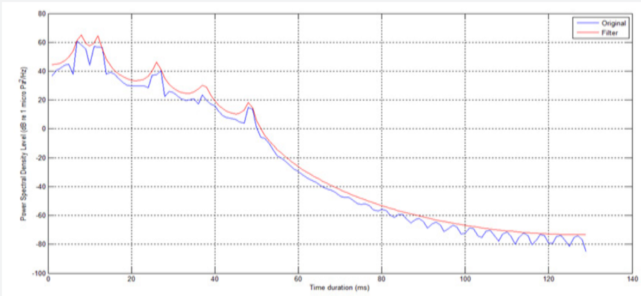

Figure 10: Relationship PSDL and Time Duration after meal of whistle sound (Original and filter).

Table 1: Regression and Anova statistics whistle sound before meals.

Regression Statistics			df	SS	MS	F	Significance F
Alpha	5%	Regression	1	0.0906652	0.0906652	0.243192	63%
Observations	25	Residual	23	8.5747191	0.3728139		
Multiple R	10%	Total	24	8.6653843			
R Square	1%						

Table 2: Regression and Anova statistics whistle sound after meals.

Regression Statistics			df	SS	MS	F	Significance F
Alpha	5%	Regression	1	0.018179	0.018179	0.057407	81%
Observations	25	Residual	23	7.2833337	0.3166667		
Multiple R	5%	Total	24	7.3015126			
R Square	0%						

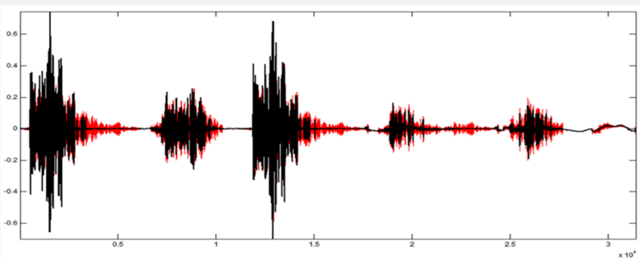

Figure 11: Denoised signal of whistle sound after meal (Red: Original Signal and Black: Denoised Signal).

Result of statistical with ANOVA will be showed in (Tables 1 & 2). In Table 1, Y = 22.5045 + 0.000097 X, and percentage of R^2 value is 1 %, percentage of Significance F value is 63% with before meal treatment. The Equation of whistle sound after meal Y = 24.2824 + -0.0000434 X (Figure 11) and have percentage of significance F value as 81 %. This shows that the value of the regression ANOVA before the meal is smaller than after meals.

Conclusion

The results in this study show Discrete Wavelet Transform (DWT) use haar wavelet (Figure 12) method has the value difference between before and after meals treatment. Patterns and values on whistle sound using the Discrete Wavelet Transform (DWT) also have differences. In the treatment DWT after meals has a value greater than the treatment before meal (Figure 13). Results of statistical analysis shows before the interval whistle meal more have greater correlation than

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before the meal, and the ANOVA results show the percentage of significance F indicates a greater value in treatment after meals.

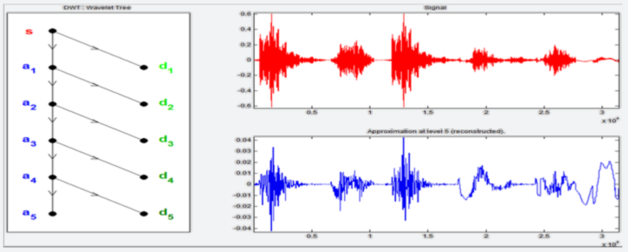

Figure 12: Haar wavelet 1 D (DWT Wavelet Tree) and approximation at level 5.

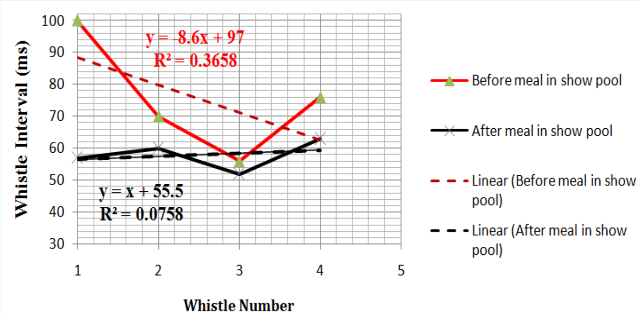

Figure 13: Whistle interval of before, and after meal treatment.

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