Sound Characteristics by Individual *Terapon jorbua*: The Basic of Bioacoustic Identification for Conservation Purposes

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ABSTRACT

Terapon jorbua which is an endogenous species in Indonesia had a serious threat due to water temperature increases as the impact of global climate change. Conservation as an effort to minimize this impact requires comprehensive information regarding various aspects of fish, including biacoustic. Passive acoustic method that using hydrophone has had been used to identify the sound characteristics of three individual fishes (total length 6, 9, and 12 cm) in aquaria at the laboratory conditions. Individual Terapon jorbua was detected produced sound at frequency in a few kilohertz with a short duration, and spectral peak above -50 dB. These characteristics are as the initial information in a series of bioacoustic identification for conservation purposes.

Keywords: *Terapon jorbua,* bioacustic, consecation

INTRODUCTION

Water temperature increases as an impact of global climate change could pressure on the aquatic ecosystem. Ficke, et al. (2007) and Brander (2009) expressed that global warming gives a serious impact on both freshwater and marine ecosystem and fisheries. Generally, freshwater and marine fish are able to adapt to environmental changes including temperature increases by physiology adaptation (Moyle and Cech, 2004). However, all of fish have a thermal range bounded on the upper end by their critical thermal maxima (CTMax) and on the lower end by their critical thermal minima (CTMin) (Becker and Genoway 1979). Although acclimation to higher-than-ambient or near-lethal temperatures (under laboratory or natural conditions) allows fish to adjust these critical limits by a few degrees (Meffe, et al., 1995; Myrick and Cech, 2000, 2003), there are limits to the magnitude and rate of thermal acclimation (Taniguchi and Nakano 2000).

Changing of fish behavior that caused by physiology adaptation may associate with sound production changes. Basic frequencies of the sound of fish will increase based on increased water temperatures, such as in *Porychthys notatus* (Brantley and Bass, 1994) and *Prionotus carolinus* (Connaughton, 2004). Kasumyan (2009) explained that sound has important role in fish behavior, including reproductive, territorial, agonistic, aggressive, social and feeding behavior. Differentiation of fish sounds types caused by varies of anatomy of sound generating organs and mechanism of production (Kasumyan, 2008). Sound production of fish has key role to study of the behavior, because visibility are difficult to seen and studied in the water. This way is might possible when some fishes could emit specific sound in frequency, amplitudes, and other acoustic characteristics. Several of organs that generate sound and mechanism of production could differentiate characteristic of sound production

Over 800 species of fishes from 109 families worldwide are known to be soniferous (Kaatz 2002), though this is likely to be a great underestimate. Vocal fish produce sounds that commonly comprise low-frequency pulses that vary in duration, number and repetition rate (Myrberg et al., 1978). The diversity of sounds made by fishes is not as remarkable as in other taxa, such as birds. Most fish show poor amplitude and frequency modulation in their sounds (see e.g. Ladich, 1997; Lugli et al., 1997; Bass et al., 1999; Kaatz, 1999) and have relatively limited acoustical repertoires; few species of fish emit more than one or two distinct sound types (Crawford, 1997).

One of the species of fish that can produce sound with a certain characteristic is *Terapon jorbua* (Ueng et al., 1991). The species that generally lives in Australia, New Guinea, Indonesia ...um temperature range between 26 to 29°C ...T) increases in 1-7°C within the next hundred ...je, 2001) will have a serious impact on the sustainability of the species. Conservation effort for this species is necessary to anticipate the potential impact of the significant increase in GMT. Comprehensive understanding of the various aspects of fish, including bioacoustic side is indispensable in determining the successfully of conservation efforts. Sound characteristics of individual fish are basic and important information in studying bioacoustic aspect of fish for conservation purposes.

MATERIALS AND METHODS

Materials

Three sizes of *T. jorbua* (total length/TL 6, 9, and 12 cm) which captured from Pelabuhan Ratu (Indian Ocean) was acclimated in a rectangular pond (5.0 x 0.8 x 1.0 m; length x width x height; water depth 0.7 m) at one month. During the acclimation period, fish was fed by artificial feed (Super-Vit®), with a chemical composition are moisture 12%; protein 30%; fat 6%; and dietary fiber 6%.

Three small aquariums (50 x 25 x 30 cm; length x width x height; water depth 25 cm) are used to performed the experiment. Environmental condition and feeding food have been set similar in the acclimation pond. The aquarium walls had been lined on the outside with rubber mattress in order to reduce excessive light and noise from the environment, except the front of aquarium. Fish in number of size (TL 6, 9, and 12 cm) was placed in the aquarium (daily temperature variability is 26 – 29^{o}C). During the experiment period, the water was circulated 30 ml/s using external water pumps and filtered by external filters.

Data Acquisition

Passive acoustic technique was used to measured sound production of fish during the experiment realization. Commonly instrumentation is used to convert the sounds product by fishes into a voltage that can be recorded and analyzed is a hydrophone (Mann, et al, 2007). The hydrophone was positioned in the center of aquarium and connected to the personal computer using data transmission wire. Data was recorded by using Wavelab Program at 2 x 1 hour (00.00 – 01. 00 am, and 00.00 – 01. 00 pm) and saved to storage devices.

Passive acoustic systems generate large amounts of raw data. Data that recorded contains true sound and some noises. To analyze the true sound that produce by fish, basic detection algorithm was used that involved the following steps (Mann and Lobel, 1995):

1. Filtering: bandpass filtering limit the signal to the frequencies containing the most energy of the fish call,
2. Rectivity and envelope: rectifying is simply taking the absolute value of the hydrophone signal. The envelope effectively "traces" the outlines of the signal so that individual pulses can be detected,
3. Smoothing: this further smoothes the signal just leaving behind a clean envelope of the pulses within a signal,
4. Gate: the gate is a simple threshold detection to identify the times when the processed signal went above a certain voltage. This threshold was set by hand, but not adjusted during data collection, so that sounds that were heard were detected by the system.

Data Analysis

Means of sound production characteristics (sound duration, spectral intensity, and dominant frequency) of individual *T. jorbua* was analyzed using One-way ANOVA. Ten sound samples (*N = 10*) of each size (TL 6, 9, and 12 cm) was used to determine the significance differences in relationship to their sound characteristics.

RESULTS AND DISCUSSION

Results. *Spectral Intensity*

Spectral intensity of each individual *T. jorbua* (TL 6, 9, and 12 cm) has been distinguished after envelope analysis, as shown in Figure 1. Although the sound data recording were performed under different noise level conditions for each individual fish, but the results of the analysis showed that there were significant differences in spectral intensity of each individual fish.

Based on the ANOVA results, there are significant differences at P<0.05 in sound spectral intensity for each individual fish (Table 1). Size of the fish gave a positive response to the spectral ... ie increasing size of the fish causes the sound ... not have a significant influence to the spectral

Sound Duration

Generally, sound duration by individual sound *T jorbua* seen almost similar for each size (Figure 1 and 2). It is shown from the ANOVA, where there is no significant difference at P <0.05 in sound duration for each individual fish (Table 2). Fish size did not provide a response to the spectral intensity, while there are significant differences between night and day period particularly on the fish with TL 6 and 9 cm. In fish 6 cm, sound duration increased at night period. In contrast in fish 9 cm, although the difference is not as much as the fish 6 cm but sound duration are increased significantly at day period.

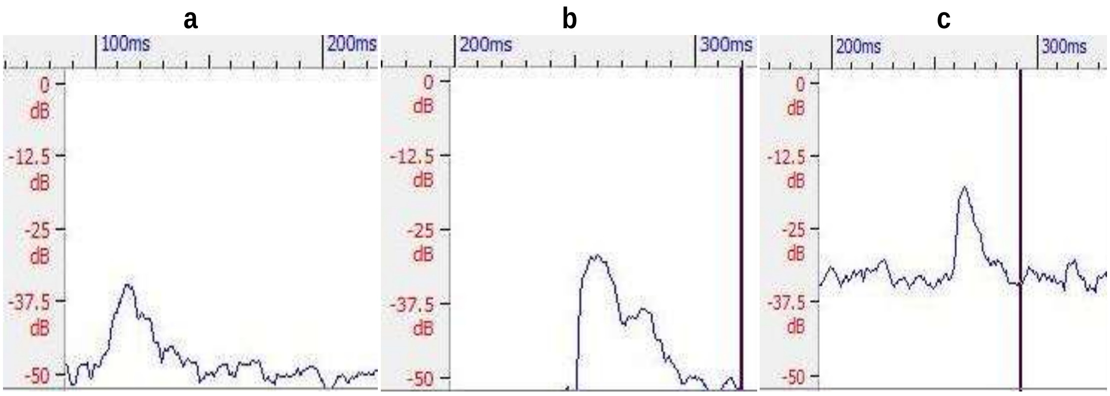

Figure 1. Sound spectral intensity of individual *T. jorbua* that measured in difference noise level (NL): (a) TL 6 cm, and NL 50 dB; (b) TL 9 cm, and NL 55 dB; and (c) TL 12 cm, and NL 35 dB. Horizontal axis describes the time duration (ms), and vertical axis expresses the spectral intensity (dB)

Table 1. Sound spectral intensity (mean±SD, minimum, and maximum in dB) of three individual *T. jorbua* (TL 6, 9, and 12 cm) at night and day period

Total Length (cm)	Time Period					
	Night			Day		
	Mean±SD	Minimum	Maximum	Mean±SD	Minimum	Maximum
6	$-44\pm2^{c\alpha}$	-12	-48	$-41\pm2^{c\alpha}$	-38	-78
9	$-31\pm4^{b\alpha}$	-35	-61	$-28\pm5^{b\alpha}$	-30	-52
12	$-14\pm3^{a\alpha}$	-25	-56	$-17\pm7^{a\alpha}$	-26	-52

N = 10; R^2 = 88.68%; *a*,*b*,*c* = Significant differences in column data (*P* < 0.05); *α*,*β* = Significant differences in raw data (*P* < 0.05);

Table 2. Sound duration (mean±SD, minimum, and maximum in ms) of three individual *T. jorbua* (total length 6, 9, and 12 cm) at night and day period

Total Length (cm)	Time Period					
	Night			Day		
	Mean±SD	Minimum	Maximum	Mean±SD	Minimum	Maximum
6	$24\pm10^{a\alpha}$	12	48	$58\pm13^{a\beta}$	38	78
9	$48\pm8^{b\beta}$	35	61	$43\pm7^{a\alpha}$	30	52
12	$39\pm10^{b\alpha}$	25	56	$41\pm7^{a\alpha}$	26	52

N = 10; R^2 = 55.61%; %; *a*,*b*,*c* = Significant differences in column data (*P* < 0.05); *α*,*β* = Significant differences in raw data (*P* < 0.05);

Dominant Frequency

Dominant frequency of each individual *T. jorbua* can be differentiated after high bandpass filtering, as shown in Figure 2. Results showed that there were significant differences in the frequency of each individual fish. Dominant frequency was increased in fish 6 cm to 9 cm, but

ferences at P<0.05 in dominant frequency for
ble 3). The same phenomenon in time period,

where the night period, the fish emits sound with a frequency higher than at day period mainly on the fish 6 and 9 cm.

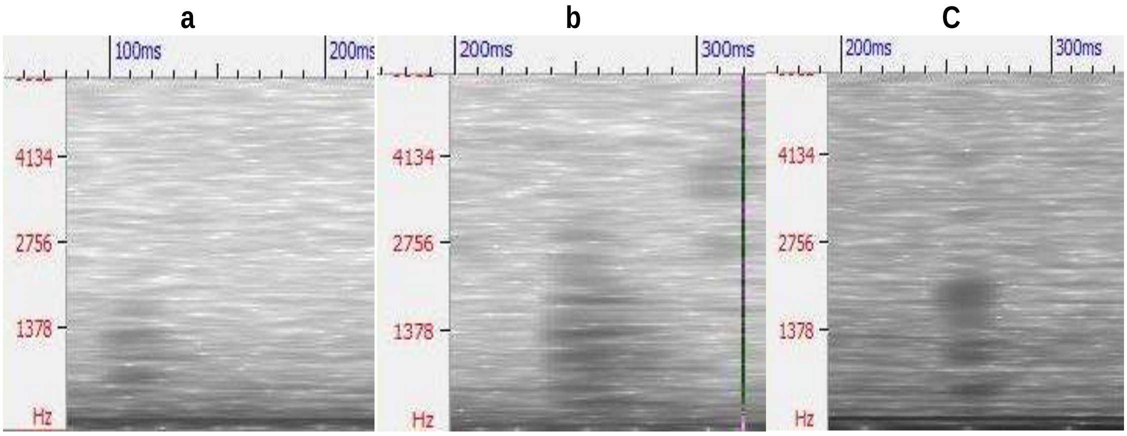

Figure 2. Sound frequency of individual *T. jorbua*: (a) TL 6 cm; (b) TL 9 cm; and (c) TL 12 cm. Horizontal axis describes the time duration (ms), and vertical axis expresses the sound frequency (dB)

Table 3. Sound frequency (mean±SD, minimum, and maximum in Hz) of three individual *T. jorbua* (total length 6, 9, and 12 cm) at night and day period

Total Length (cm)	Time Period					
	Night			Day		
	f_{avrg} (Hz)	f_{max} (Hz)	f_{min} (Hz)	f_{avrg} (Hz)	f_{max} (Hz)	f_{min} (Hz)
6	$1,403\pm164^{a\alpha}$	1,205	1,701	$2,164\pm220^{a\beta}$	1,937	2,627
9	$2,691\pm621^{b\alpha}$	1,744	3,402	$3,115\pm615^{c\beta}$	1,614	4,059
12	$2,814\pm888^{b\alpha}$	1,685	4,062	$2,549\pm320^{b\alpha}$	2,039	3,007

N = 10; R^2 = 54.00%; %; *a*,*b*,*c* = Significant differences in column data ($P < 0.05$); *α*,*β* = Significant differences in raw data ($P < 0.05$);

DISCUSSION

Individual *Terapon jorbua* in various size (TL 6, 9, and 12 cm) were able to produce sound (click) with spectral intensity above -50 dB, frequency a few kilohertz, and duration no more than 100 ms. The sound that emitted could be a single click, double click and even established a series of tones. It is not overly much different in terms of sound generating organ and mechanism of sound production with other species of the same genus, i.e. *Terapon theraps* that have been studied by McCauley and Cato (2013). The sound generating organs in Terapontidae that has been explained by Schneider (1964) and Vari (1978) are a two chambered swimbladder, the posterior chamber being approximately twice as long as the anterior, the two connected by a narrow open tube surrounded by a sphincter muscle. Attached to the anterodorsal surface of the anterior chamber are laterally-paired extrinsic-muscles. These extend anterodorsally to attach on the posterior surface of the ventral process of the post temporal or the rear of the skull. However, differences species of the same family will influence several of sound characteristics, such as spectral intensity, duration and dominant frequency.

Differentiation of sound characteristics that produced by individual *T. jorbua* caused by changing in size of sound generating organ and the mechanism of sound production. This mechanism is probably similar to the mechanism that identified in *Metriaclima zebra* (Bertucci, et.al., 2012) and *Oreochromis niloticus* (Longrie *et al*., 2009). Sounds would result from movements of the swimbladder due to the contraction of a set of muscles located close to it. Consequently, larger individuals with a larger swimbladder will produce sounds with lower frequencies. Likewise, if sounds are produced by the contraction of sonic muscles, larger muscles will generate more and longer sounds with a lower frequency. The correlation between sound features and the morphology (size) of the sender may thus help to identify large and small individuals.

night and day period of *T. jorbua* are as a Kinney (1988) explained that diurnal activities s the time of day are probably responsive to endogenous changes of either the endocrine or the neutrally alert mechanism. If hormones could actually modulate the neurological output of pattern generators in the brain (Demski et al., 1973), it is likely that the diurnal calls of *T. jorbua* could be also controlled by endogenous mechanism.

CONCLUSIONS

T. Jorbua as Indonesian endogenous fish is able to produce sound with specific characteristics that provides essential information regarding to their existence and behavior in the waters. Characteristics of fish sound were greatly influenced by the swimbladder size which evolves with increasing the fish size. In addition, the hormonal mechanisms of fish that caused by environmental changes in day and night period also gives a significant impact on the sound characteristics that their emitted.

The conservation of *T. jorbua* as effort to anticipate the water temperature increases as the impact of global climate change requires comprehensive information regarding the fish, including fish bioacoustic which is an integral aspect of their behavior. This study only provides initial information so that required a series of further researches which will examine the comprehensively of fish bioacoustic. Several aspects that needed to be studied in the future are a daily sound production of fish, sound representation to fish behavior, acoustic response and acoustic threshold of fish to the water temperature increases.

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