Sound characteristics of *Terapon jorbua* as a response to temperature changes

Amron¹,², I Jaya², T Hestirianoto², K v Juterzenka²

¹Marine Science Department, Jenderal Soedirman University, Kampus Unsoed Karangwangkal, Purwokerto 53122 Indonesia
²Marine Science and Technology Department, Bogor Agricultural University, Kampus IPB Darmaga, Bogor 16610 Indonesia

Abstract. The change of water temperature has potential impact on the behavior of aquatic animal including fish which generated by their sound productivity and characteristics. This research aimed to study the response of sound productivity and characteristics of *Terapon jorbua* to temperature change. As a response to temperature increase, *T. jorbua* to have decreased the number of sound productivity. Two characteristic parameters of fish sound, i.e., intensity and frequency as were quadratic increased during the water temperature rises. In contrast, pulse duration was quadratic decreased.

1. Introduction

Water condition has an important role for aquatic organism. The change of water parameter may influence the existence of the biota. Temperature is one of the main parameters that could potentially elevate during the global climate change. The global impact of the climate change is increasing in global mean temperature (GMT), which approximately increased 3–4°C has impact to many aspects such as sea level rise, agriculture, water resources, human health, energy, terrestrial ecosystems productivity, forestry, biodiversity, and marine ecosystems productivity [1]. Potential impacts of global warming to the water ecosystem and resources have been studied. [2-6] are investigated the global warming impact to aquatic ecosystem, from the polar terrestrial to marine ecosystem. The other study, [7-12] are studied the impact of global warming on the benthic, fish, and other organism communities. The most important factor that contributes to ecosystem changes is the rise of sea temperature as global warming consequences.

Almost of freshwater and marine fishes are exotherms that cannot regulate their body temperature through physiological means and whose body temperatures are virtually identical to their environmental temperatures [13]. Much of the research on the behavior of fish as a response to temperature changes have tended to focus on generally fixed patterns of behavior [14]. However, most water environment characteristics especially temperature tends to be an important factor to change the fish behavior. [15] Analyzed that dial temperature could be changes the migration behavior and orientation of chum salmon. [16] Founded that vertical movement and behavior of Pacific bluefin tuna are depended by temperatures gradient in the vertical water column. [17] Studied and concluded that increases in stream temperatures in Arizona had reduced the habitat available for native fishes and therefore had favor those non-native species with higher thermal tolerances.

The alteration of fish behavior may associate with a variety of fish production. During reproductive, territorial, agonistic, aggressive, social and feeding, the sound production by fish may have different characteristics [18]. Sound production of fish plays an important role in studying fish behavior because the performance of fish is difficult to be conducted and studied in the ocean. Therefore, analyzing fish sound might be a possible way to understand their behavior when some
fishes could emit specific sound in frequency, amplitudes, and other acoustic characteristics. Study on acoustic behavior of marine fishes due to the rise of temperature could be developed, especially to stenothermal (narrow thermal range) species, like terapon. The species that included in the family of Teraponidae or terapons (thornfishes, grunters, or tiger perches) has tolerance range in sea temperature 25.86-29.04°C and salinity 31.94-35.18 psu (www.fishbase.org).

2. Material and method

2.1 Materials
Terapon jorbua harvested fishermen in Pelabuhan Ratu Bay, Indian Ocean was transported and acclimated in laboratory. Fish was fed by artificial feed (Super-Vit®), with a chemical composition are moisture 12%; protein 30%; fat 6%; and dietary fiber 6%. During the experimental realization, water was circulated 30 ml/s using external water pumps and filtered by external filters.

2.2 Experimental setting
Two specimens of T. jorbua in 80-100 mm size (1B₁ and 1B₂) was placed in each of small aquarium (50 × 25 × 30 cm; length × width × height; water depth 25 cm). In the other similar size of aquarium, two specimen fishes (2B₁ and 2B₂) with similar size were placed. In this study, two replications were conducted to minimalize the random error (Figure 1). Water temperature is increased ± 2°C every 2 days by using the water heater. It was 29 ± 1°C in the starting period, and 33 ± 1°C in the last period. A light condition in the laboratory reis adjusted to the environmental conditions during the day and night period without additional lighting.

2.3 Data acquisition
The video system is used to takes data of fish behavior during resting, territorial, aggressive, and social behavior. The video system was placed in front of the aquarium. The passive acoustic technique was used to measures sound production of fish as long as the underwater camera recorded. Commonly instrumentation was used to convert the production of the sound from fishes into a voltage that can recored and analyzed is a hydrophone [19]. The hydrophone was positioned in the center of aquarium. Both the video camera and hydrophone was connected to personal computer to record audio and visual signal synchronously.

2.4 Data analysis
Sound productivity based on fish behavior in every observation time was analyzed descriptively to explain the relationship between sound productivity to water temperature. Variability of sound characteristics during the rise of water temperature was analyzed by curve fitting.
3. Results and Discussion

3.1 Results

3.1.1 Response of sound productivity of fish to temperature change. One of sound parameters which can be measured to representing the changes of fish behavior as an impact of climate changes is sound productivity. The optimum temperature of *T. joruba* in nature habitat is 26 – 29°C, however, that was increased during the climate changes and has influenced the sound productivity of fish. Simulation results showed the sound productivity of fish was significantly decreased during the level of water temperature increased after the optimum temperature (Figure 1). Based on two sound types produced by *T. joruba*, the productivity of “click” sound was changed compared to “frog” sound. The alteration of click sound productivity happened in all observation period, dawn (05 - 07 h), peak of the day (11 – 13 h), dusk (17 – 19 h), even in peak of the night period (23 – 01 h). In the dawn period, sound productivity at temperature 29 – 30°C rose to the peak when it neared at 06 - 07 h (Figure 2a).

In the same way when the temperature was 31 – 32°C, sound productivity achieved the peak at 06 h. On the other hand, sound productivity dropped at nearly 07 h. The changes of sound productivity were significantly shown when the temperature rose up to 33 – 34°C. This situation appeared when the fish experienced similar sound productivity in this period. Therefore, there were almost none of sound productivity peak at the water temperature 29 – 30°C and 31 – 32°C. In the peak of the day (temperature 29 – 30°C), the sound productivity was relatively high during this period (Figure 2b). Sound productivity decreased was displayed when the temperature rose up to 31 – 32°C, it was relatively low before achieved the peak of the day (12 h), and rose afterward. Contrast sound productivity revealed when the temperature achieved 33 - 34°C, the sound productivity decreased during this period. The tendency of sound productivity pattern that decreased during the water temperature increases also happened at dusk and the peak of night period. In the other hand, sound productivity was relatively high at temperature 31 – 32°C during at dawn and peak of the day period (Figure 2c, and 2d). Sound productivity was decreased when the temperature climbs up at 31 - 32°C, and it was continuously decreased at temperature 33 -34°C.

3.1.2 Response of sound characteristics of fish to temperature changes. As similar with *T. joruba* sound productivity, sound characteristics (intensity, frequency, and duration) were also changed along the rise of water temperature (Figure 3). Sound characteristics either click or frog sound had a quadratic increase during the increase of water temperature. Even if the intensity, frequency, and duration of frog sound were higher than click sound, both of the sound types had almost similar increased pattern.

The intensity of fish sound either click or frog sound had quadratic elevation along the rise of water temperature (Figure 3a). The increase of intensity average was first shown when the temperature elevates from 29 – 30°C to 31 – 32°C, and variability of intensity revealed when water temperature elevates up to 33 – 34°C. Simulation results indicated that fish sound intensity would simultaneously escalate along with the elevation pattern of intensity when the water temperature increased. The intensity of click sound which produced by the fish had sharper elevation than frog sound, especially at water temperature below 34°C.

Another sound characteristic which also had similar elevation pattern along the rise of water temperature was frequency (Figure 3b). Fish sound frequency either click or frog sound had quadratic increased along with the escalation of water temperature. A sharp increase in frequency exhibited when the water temperature rose up to 33 – 34°C, and continuously showed considerable elevation along with the addition of water temperature. On the other hand, the intensity and frequency of sound either click or frog had relatively similar pattern.
Figure 2 Sound productivity of *Terapon jorbua* recorded in temperature level: 29-30, 31-32, and 33-34°C. (a), (b), (c), and (d) respectively represents recording time at 05-07, 11-13, 17-19, dan 23-01 h
There were significant differences in intensity and frequency, meanwhile pulse duration had quadratic decreased along with water temperature increased (3c). Pulse duration either click or frog sound was dropped when the water temperature rose up to 33 – 34°C. Pulse duration continuously depleted along with the increase of water temperature. A different pattern of depletion of pulse duration revealed between click and frog sound, whereas click sound had sharper decrease pattern than frog sound. The larger range of pulse duration of frog sound tends to cause it sharper elevation than the pulse duration of a click sound.

3.2 Discussion

The decrease of sound productivity of *T. jorboa* during the rise of water temperature was highly related to changes in their behavior. One reason that possible to describe this phenomenon is the influence of temperature on the muscle ontogeny of the fish [20]. Different temperatures lead to variation in body muscle mass (regardless size and number of muscle fibers) that directly affect the swimming ability. In the case of zebrafish, Hjoston *et al.*, (2009) revealed that the optimal embryonic temperature for fast muscle fiber recruitment (hyperplasia) is at 26°C, as in that temperature there were 18.8% more fast fibers than at 22°C and 13.7% more fibers than at 31°C. The increase of swimming ability changed the territorial behavior to aggressive behavior [20]. As the consequences, this change affected the decrease of productivity of click sound.

Besides changing the sound productivity, the rise in water temperature also has impacted the sound characteristics of *T. jorboa*. The elevation of water temperature affects to raise the intensity, frequency, and to decrease the pulse duration. This condition is similar to Connaughton *et al.*, (2000) investigation, reported that sound pressure level, repetition rate, and dominant frequency of weakfish are increase, but pulse duration is decrease during water temperature increases [21]. With an elevation in water temperature, the rate of exchange of calcium ions in tympanic muscles responsible for sound generation increases [22], and, as a consequence, the schedule of their work changes substantially, which, in turn, is reflected in most parameters of sounds produced by fish. In *Polymyrs marianne* and *P. adspersus*, Q10 coefficient is close to 2.07 for the amplitude of the sound of the moan type and for the duration and frequency of a sequence of pulses in grunt sounds [23]. A decrease in the duration of acoustic pulses, an increase in the rate of their generation, and an increase in the frequency of the sound and the level of acoustic pressure that accompany water temperature increase were found in many fish [24, 21]. The nature of these changes is related to temperature effects on the work of the center regulating acoustic activity and is common for all fish [24]. The intensification of sound generation with water temperature increase takes place parallel to an increase in the behavioral activity of fish [25].

A distinctly pronounced positive linear dependence on temperature is also exhibited by the level of acoustic pressure of anxiety sounds and their dominant frequency while the duration of pulses with an increase in temperature successively decreases [21]. The dominant (basic) frequency of sounds of males of plainfin midshipman *P. notatus*, oyster toadfish *O. tau*, and Lusitanian toadfish *H. didactylus* depends on water temperature similarly [26, 27]. In *Prionotus carolinus*, basic frequency increases by 43 Hz with an increase in temperature by 2.5°C [28]. In *Eutrigla gurnardus*, the duration of pulses in sounds of the grunt type noticeably decreases with a seasonal increase in water temperature [29].
Figure 3 Sound characteristics of *Terapon joruba* recorded in temperature level: 29-30, 31-32, and 33-34°C. (a) Intensity, (b) frequency, and (c) pulse duration.
4. Conclusion

Increases in water temperature have an impact on the existence of Terapon jorbua which can be represented by the changes in productivity and characteristics of sound that they produced. The sound productivity of fish decreased during the increase of the water temperature. The sound productivity of fish decreased during the rise of water temperature. Sound characteristics that have been quadratic increases along the increase of water temperature were intensity and frequency. Meanwhile, another characteristic, pulse duration has quadratic decreased due to the rise of water temperature. Temperature range of this study still very limited caused it was difficult to predict the stress threshold of fish. Therefore further investigation by giving preferential treatment in wider temperature range is needed.

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