Bioacoustic of *Anguilla bicolor* (Mc Clelland, 1844) feeding behaviour under controlled conditions

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Abstract. Research on the behavior of eels with bioacoustics has never been done, because eels are catadromus fish that lay eggs in the deep sea and then grow in freshwater area. This study aims to observe the behaviour of *Anguilla bicolor* when feeding with passive sonar bioacoustic methods by hydrophone in the elver and yellow phases. The eel is placed in an aquarium and fed with pellets. The data were processed to get the duration and characteristics (frequency and intensity) of sound. Data were analyzed using the Duncan Multiple Range Test (DMRT) to determine the difference in the sound of eel before and during feeding. The results showed that the duration of the sound of the elver phase fish was significantly different for the duration before and after feeding, but for the yellow phase, the duration before and after feeding was not significantly different. When compared between the elver and yellow phases for before and when feeding both are significantly different. The sound pattern of elver phase itself is significantly different for before and after feeding, as well as for the yellow phase. When compared between the elver phase and the yellow phase on the sound pattern before feeding it was not significantly different, so did the sound pattern of the elver phase when feeding was not significantly different than the yellow phase sound when feeding. The conclusion of this study shows that the bioacoustic of eel fish comes from the movement of fish when swimming. Each phase of eel has different sound characteristics seen before feeding or when feeding.
Key Words: movement, bioacoustic, spectrum, behaviour.

Introduction. Fish bioacoustic research has been conducted since the 1960s by Professor William N. Tavolga and have been applied to several biotas including fish (Lobel 2001; Webb et al 2008). Bighead carp bioacoustic has been carried out by Taylor et al (2005), guppy fish bioacoustic by Lubis et al (2015), marine mammalian bioacoustic by Wahlberg et al (2001), Croll et al (2002), and Lubis et al (2018). Favaro et al (2011) conducted a study on red swamp crayfish and Patek et al (2009) conducted a research on spiny lobster.

Eel fish has high economic value and is an export commodity from the fisheries sector (Purwanto 2007). The eel export market includes Japan, Hong Kong, Germany, Italy (Affandi 2005). Tropical eel (*Anguilla bicolor*) is found in Africa, India, Sri Lanka, Bangladesh, Myanmar, Indonesia and Australia (Arai et al 2012).

The eel has a metamorphic process from eggs - larva - elver - yellow - silver. Changes in the eel phase not only affect the increase in length and weight of fish, but the fish also experience changes in pigments in the body (Jegstrup & Rosenkilde 2003). In Indonesia, eel fish larvae are found in river estuaries. Catching is carried out by fishermen and then the larvae are reared in cultivation ponds, where artificial feed is provided (Arief et al 2011). Research on the behaviour of eel by passive sonar method has not been widely done. This is because fish spawn in deep sea waters and adult phases are found in river estuaries in hiding holes. In nature, eels are active at night by searching for fish so that observing the behaviour of eels is difficult. This study aims to observe the behaviour of eel (*Anguilla* sp.) when feeding with bioacoustic methods in the elver and yellow phases.

Material and Method

Time and place research. The research was conducted on 4-7 August 2016 in the Laboratory of Histology and Embryology at the Faculty of Biology, Gadjah Mada University. Data processing was carried out at the Acoustic and Marine Instrumentation Laboratory, Department of Marine Science and Technology, Faculty of Fisheries and Marine Sciences, Bogor Agricultural Institute.

Tools and materials. This research was carried out in a controlled manner, in a room where fish are kept in an aquarium equipped with paralon as a place of hiding and an aerator as a producer of oxygen. Voice recording uses headphones, hydrophones, alkaline batteries, folding computers. The research material used 5 yellow phase eels with a length range of 9.30-9.80 cm and 5 elver phase fish with a length range of 51.40-62.10 cm. Figure 1 depicts the eel and equipment used.

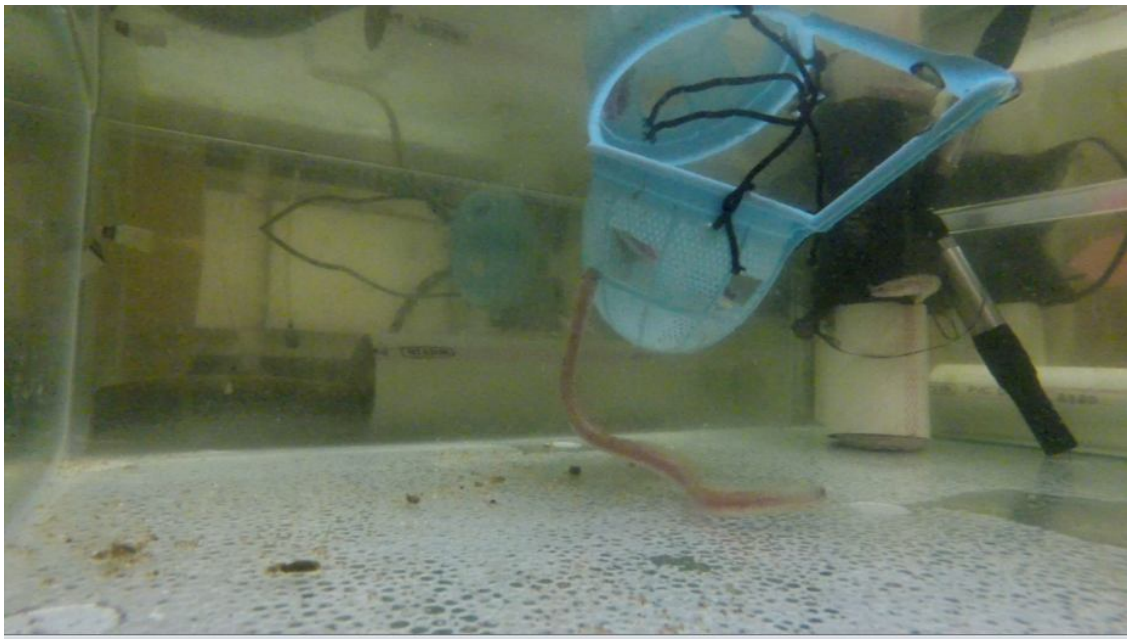

Figure 1. Eel in the equiped aquarium.

Data recording. When recording sound, all instruments that are expected to cause interference are turned off. The hydrophone is placed in the aquarium so that the sound produced by fish movement can be recorded properly. The recording is done before and during feeding, with a recording duration of 10 minutes each. Recordings are stored in the form of data with the .wav extension.

Data analysis. The sound of fish recorded when feeding in the .waw extension then processed with an advanced program to get the desired sound of fish. Sound data that has been found is then sampled and analyzed using 3D analysis to obtain information about time and frequency. Furthermore, FFT analysis is carried out and exported to the * txt program. The results of data processing are the duration and sound characteristics. The processing data is continued to be tabulated and then the statistical description and analysis are carried out using the Duncan Multiple Range Test (DMRT) to determine the difference in the sound of eel before and during feeding.

Results and Discussion. Eel is currently cultivated a lot, some mass media said that in addition to the selling price in the local market which is quite high, eel also has export opportunities, especially to Japan. A number of sources said that consumption of eel in Japan in one year could reach more than 100,000 tons. While the production capacity of eel in Japan is only 60,000 tons per year so that the shortfall is met through imports

from a number of countries, including Indonesia and China (Ant 2017). Nijman (2015) states that there has been an increase in eel exports in Indonesia since 2013.

As we stated before, the research bioacoustics was done on some biota that is able to produce sound through organs such as whales, dolphins, gerot-gerot fish (*Terapon jorbua*), shrimp, but the sounds also come from the biota's movement. Colson et al (1998) stated that the sound of fish is also predominantly produced by the pectoral fin when fighting over food. Fish & Mowbray (1970) also stated that many sounds produced by fish are pulsatile. Lagler et al (1977) in Nessa (1985) explain that there are several types of movements in fish swimming. One of them is anguilliform form, which means the fish swim like snakes crawling. This eellike movement is the one who produces sounds.

The results of processing the sound data of fish, showing the sound spectrum before and during feeding showed the duration of sound is different for the elver phase and the yellow phase. Before feeding, the elver phase eel has a sound duration longer than the yellow phase. Overall the sound duration before feeding for both elver and yellow phase is longer than when feeding (Table 1). This is possible because fish with two phases have a long enough movement before feeding compared to the movement when feeding. At feeding, fish tend to move slightly. This is presumably because the eel has found the feed.

Table 1

The average duration of the sound of eel before and during feeding

Description	*Elver*	*Yellow*
Before feeding (s)	48.84	29.61
Feeding (s)	18.21	27.23

Based on the results of the Duncan Multiple Range test analysis (Table 2), each phase has a different duration where the elver phase is significantly different for the duration before and during feeding, but for the yellow phase, the duration before and during feeding is not significantly different. When compared between the elver phase and the yellow phase before and when feeding, both are significantly different.

Table 2

Duration of feeding behaviour in elver and silver phase fish

Sample	*Duration (s)*
Elver before feeding	48.83 ± 46.2^{b}
Elver feeding	29.61 ± 30.42^{c}
Yellow before feeding	18.21 ± 17.39^{a}
Yellow feeding	27.23 ± 28.83^{a}

Letters that are behind the same number show no difference in the DMRT test with a confidence level of 95%.

When sampling, the eel sound data is easily detected, this is because when the sound of eel is recorded there is no interference so it is easily observed. The eel sound pattern gives a frequency range from 0 to 22.028 KHz, with the dominant frequency in the range of 151-450 Hz. Based on the dominant frequency range from 150 to 450 Hz, the intensity of the sound of the elver phase eel is generally higher than yellow phase at the time of feeding or when feeding (Figures 2 and 3). Sound characteristics of the elver phase itself has a higher sound intensity when feeding than before feeding (Figure 4), but for the characteristics of the yellow phase sound does not differ much between before feeding and when feeding (Figure 5). The trend of the sound of eel is different from the sound of guppy fish when feeding (Lubis et al 2015) and also of the sound of terapon fish (Amron 2014).

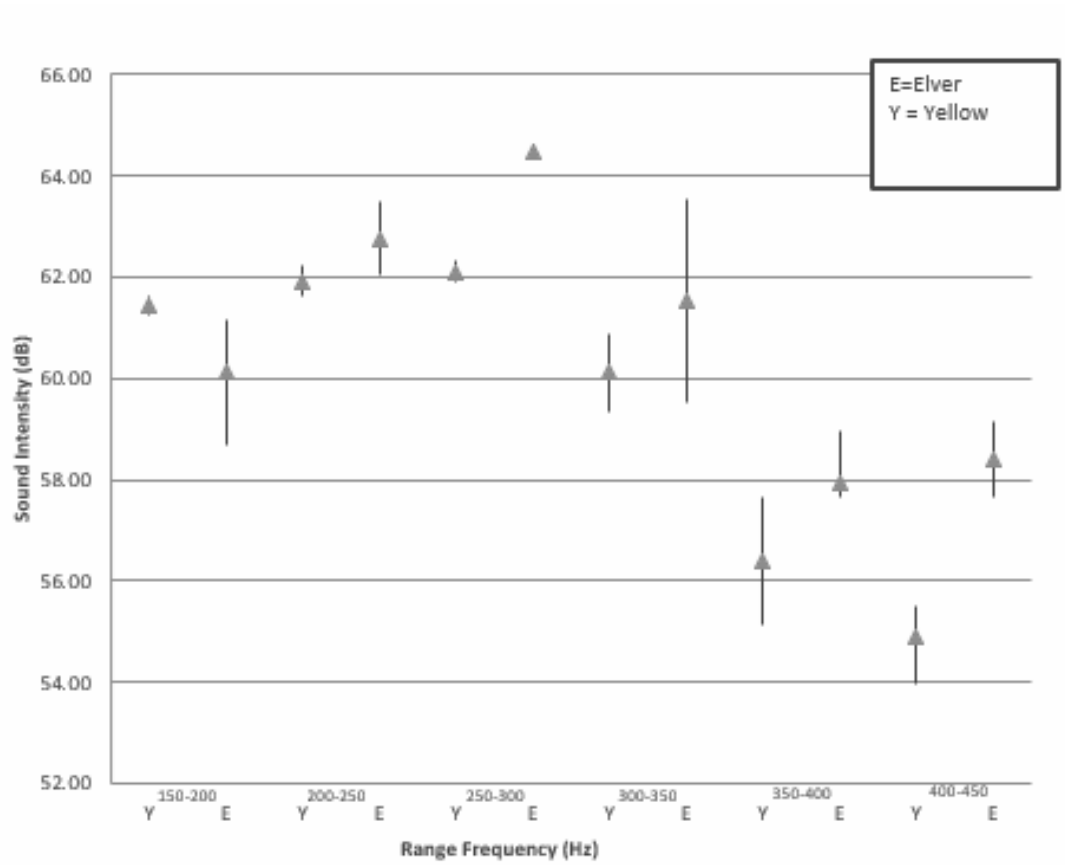

Figure 2. The sound intensity at range dominant frequency of elver and yellow before feeding.

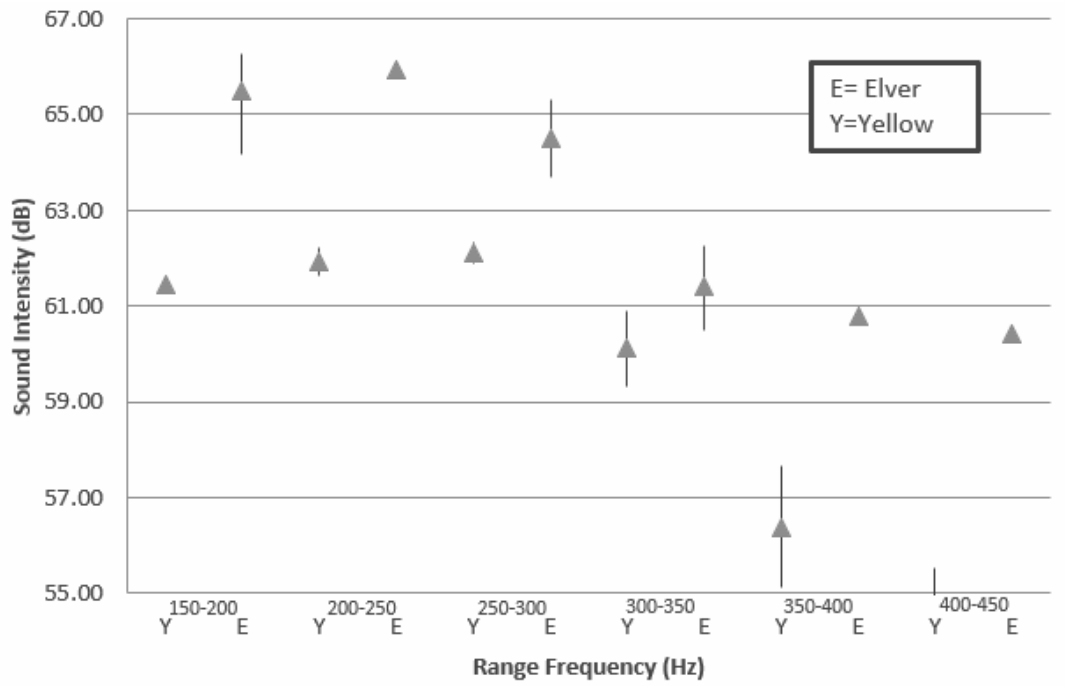

Figure 3. The sound intensity at a frequency range (elver and yellow) at feeding time.

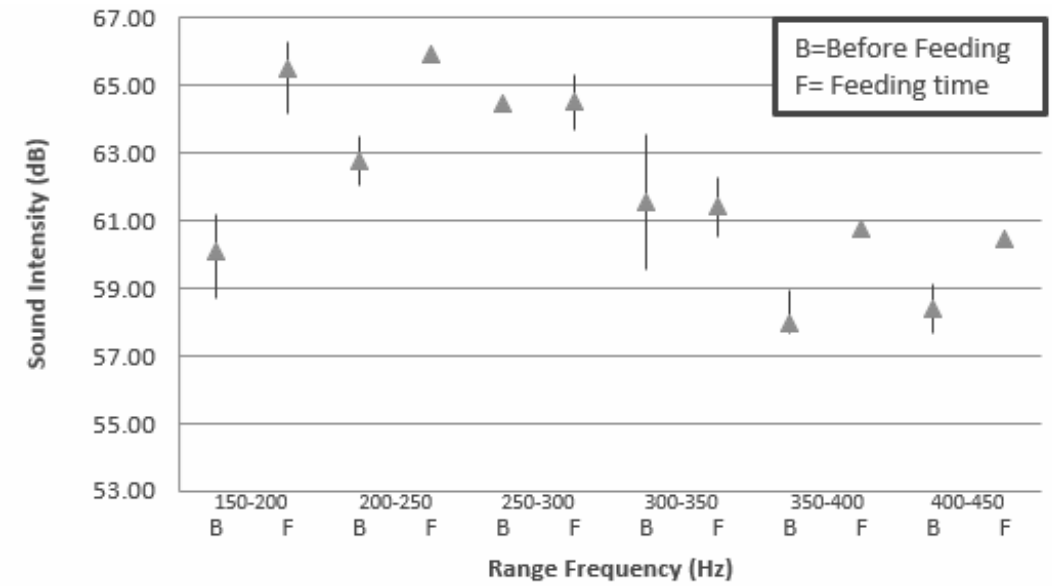

Figure 4. The sound intensity at range dominant frequency of elver phase.

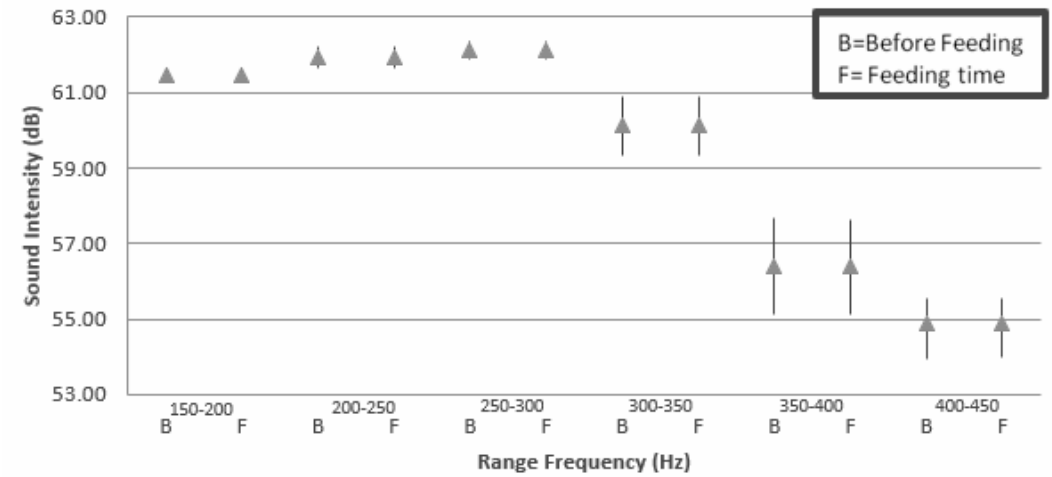

Figure 5. The sound intensity at range dominant frequency of yellow phase.

In general, the intensity of the sound of fish in elver and yellow phases before feeding and during feeding has the same trend based on the frequency range (Table 3). The intensity increases (+) at frequencies of 150 to 300 Hz then decreases (-) from frequencies 300 to 450Hz. However, the average value of sound intensity is different.

Table 3

Sound intensity in the frequency range

Description	*Frequency range (Hz)*					
	150-200	*200-250*	*250-300*	*300-350*	*350-400*	*400-450*
Elver before feeding	+	+	+	-	-	+
Elver during feeding	+	+	-	-	-	-
Yellow before feeding	+	+	+	-	-	-
Yellow during feeding	+	+	+	-	-	-

Based on the results of the Duncan Multiple Range test analysis (Table 4), the sound characteristics of the elver phase are significantly different for before and during feeding, as well as for the yellow phase is significantly different for the sound patterns before and during feeding. When compared between the elver phase and the yellow phase on the characteristics of the sound before feeding there was no significantly difference, so did

the sound pattern of the elver phase when feeding was not significantly different from the yellow phase sound when feeding.

Table 4

Sound patterns of elver eel and silver eel phases of feeding behaviour

Sample	*Intensity (dB)*
Elver before feeding	60.74±2.34[a,b]
Elver during feeding	62.96±2.35[c]
Yellow before feeding	59.35±2.91[a]
Yellow during feeding	61.41±2.68[b,c]

Letters that are behind the same number show no difference in the DMRT test with a confidence level of 95%.

Conclusions. This research shows that eel bioacoustic comes from the movement of fish when swimming. Each phase of eel has different sound characteristics at the time before feeding and feeding. The elver phase and the yellow phase on the characteristics of the sound before feeding there was no significantly difference, so did the sound pattern of the elver phase when feeding was not significantly different from the yellow phase sound when feeding.

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