Underwater Noise for a Variety of Traditional Fishing Boats in Cilacap Waters, Indonesia

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Abstract

As the main contributor to noise pollution in Cilacap waters, the noise characteristics of traditional fishing boats based on distance are very important to be studied. This research aimed to determine noise intensity and frequency based on the distance for each traditional fishing boat (3, 5, and 10 GT). The results showed that these boats emitting noise with broadband frequency and receive levels reached 153 dB re 1 µPa. The noise characteristics were different for each type of ship due to differences in the size, engine type, and operational speed. The receive level had the same decreased pattern based on the distance for each noise frequency, but with a different intensity. Meanwhile, the noise frequency had increased quadratically based on the distance, where the higher frequency, the greater change so that the noise was not detected faster.

Introduction

The practice of traditional fishing boat in Indonesia is used as the main transportation to optimize fisheries resources. It is made from simple technology and relies solely on the knowledge and experience of its makers. This is because the ship's tonnage is determined only based on the size[1]. Furthermore, variation in tonnage causes differences in the ship's operating area following the national laws and regulations[2–4]. In the context of current regulations, traditional fishing boat is classified as small-scale fisheries, which ought to increase annually due to the optimization of resources[5]. The increase in added value and market demand for catches from small-scale fisheries businesses has also triggered an increase in the number of traditional fishing boat[6].

However, increased number of traditional fishing boats in Cilacap Waters poses a dilemma to optimize and create pressure on fisheries resource. Shipping activity such as fishing is a major contributor to noise pollution in waters[7,8]. This has been evident in several studies, which prove that ships produce low-frequency noise with varying intensity[9–15]. The other sources are contributed by another anthropological activities[16–19], marine biota[20–26], and physical processes[27–29]. Despite being the main source of pollution in the waters, noise produced from vessels only has a frequency below 1 kHz with an intensity below 100 dB[30].

However, some vessels emit broadband frequency with relatively high intensity. This is closely related to the difference in the size of the ship, strength of engine and operational speed. Furthermore, small ships that are usually equipped with high-speed engines produce high frequencies[31]. On the contrary, larger ones produce lower frequencies[7]. An increase in noise occurs when the ship is operated[32], due to a combination of engine, propeller propulsion and hydrodynamics[33]. The difference in the size of fishing vessels equipped with various types of engines causes the operating speed to be different. The consequence is that the noise produced by ships operating in Cilacap waters also varies. When this happens continuously, it will certainly have an impact on the existence of aquatic biota since the ability to adapt also differs from one species to another[8,34].

Previous studies have shown that anthropogenic noise from ships affects the existence of marine life. The impact on marine mammals is in the form of stress[35,36], leading to behavioral[37], physiological changes[38,39], other physiological effects[40], population dynamics[41,42], as well as damage to the hearing system[43]. Meanwhile, the impact on fish is in the form of stress[44,45], physiological effects[46,47], changes[9,48] and physical damage to the hearing system[49]. Due to the enormous impact on aquatic biota, the presence of noise in Cilacap waters needs to be investigated for its source and as good as the quantity of pollution it produces. Therefore, this study aims to determine the sound characteristics, both frequency and noise intensity, as well as changes based on distance in several types of traditional fishing boats (3, 5, and 10 GT).

Methods

Recording's site and system. Noise emissions from three type of local fishing vessels (3, 5 and 10 GT; Fig. 3) which pass the lane of Cilacap Fishing Port in September 6–8, 2019 were recorded using calibrated omnidirectional hydrophone (Sea Phone SQ26, sensitivity − 194 dB re 1 V.μPa^{-1}, 20 Hz to 45 kHz flat response). It was connected to sound recorder (20 dB gain, 16-bit, 4,410 Hz sampling rate and stored in .WAV file) and the hydrophone was installed in KP. Napoleon 33 (fishery patrol boat) that tethered in 7°43'35.13" S and 109° 1'25.09" E was buoyed approximately 1.5 m under the sea surface. Traditional fishing boat passed the inner and outer lanes were recorded using HD CCTV camera (1080 MP). Both sound and video recordings were synchronized and connected to Zoom H1n digital flash recorder and displayed to LCD monitor. Sound and video recording was conducted continuously during the study.

Data analysis. Noise intensity and frequency were determined by envelope and power spectral density (PSD) analysis from sound recordings. Meanwhile, the type of vessel that emits noise were analyzed based on video recordings. The distance of the ship to the deployed hydrophone was a projection of the vessels movement that was recorded by CCTV camera to the map and validated based on the speed. The pattern of changes in intensity based on distance for each vessel was analyzed from the PSD of each frequency (1, 5, 10 and 15 kHz). Meanwhile, the pattern of frequency changes was analyzed by interpolation for each frequency group (< 1, 2–3, and > 4 kHz).

Results

Soundscape. The noise characteristics for receive level and peak frequency vary based on differences in traditional fishing boat (Table 1). The highest noise intensity was produced by 3 GT fishing boat, where the receive levels reached 153.0 dB re 1 μPa. With almost similar distance to the receiver position, receive level of noise for 5 and 10 GT fishing boats reached 146.8 and 149.8 dB re 1 μPa, respectively. These variations were closely related to the difference in source level, ship size, engine's type and strength, as well as the operational speed of the vessels. The 3 GT fishing boat emitted the highest noise intensity because it was equipped with 20 HP gasoline-fueled outboard engine. With a small size and equipped engine power, it can travel at speeds up to 3.1 m s^{-1}. The high operational speed causes the resulting noise intensity to be high due to the combination of engine, propeller and hydrodynamics. It was different from the 5 GT fishing boat, which can only operate at a speed of 1.9 m s^{-1} leading to a decreased intensity of noise. In other cases, where a 10 GT fishing boat equipped with a different type of engine (diesel-fueled inboard engine) and a power of 120 HP produced a higher noise intensity than a 5 GT type. Despite having the highest engine power, the ship's operational speed of only 0.9 m s^{-1} influenced the receive level of this vessel to be lower than the 3 GT fishing boat. Therefore, the intensity of noise produced by the ship was more dominantly influenced by the operational speed and other factors such as engine's type and strength.

Table 1
Noise characteristics for variety of traditional fishing boat.

Type of traditional fishing boat	Receive level (dB re 1 μPa)	Peak frequency (Hz)
3 GT (8.25 m of length and 1.2 m of width) with gasoline-fueled outboard engine (20 HP and 3.1 m s^{-1} of speed operation)	153.0	1,100
5 GT (11.00 m of length and 2.6 m of width) with diesel-fueled inboard engine (45 HP and 1.9 m s^{-1} of speed operation)	146.8	1,886
10 GT (13.50 m of length and 2.8 m of width) with diesel-fueled inboard engine (120 HP and 0.9 m s^{-1} of speed operation)	149.8	1,632

In contrast to noise intensity, the highest peak frequency was produced by a 5 GT fishing boat that reached 1,886 Hz. However, it had the highest peak frequency that can be heard at 8 kHz. The 3 and 10 GT fishing boats have frequency range which can reach the audible sound threshold (20 kHz). Their peak frequency was lower which is only 1,110 and 1,632 Hz respectively. Furthermore, gasoline-fueled outboard engine type produced higher noise frequency than diesel-fueled inboard engine. The power of the engine contributed greatly to this condition. Also, the wide range of noise frequencies produced by the 3 GT fishing boat was more reasonable because the ship's operating speed was higher. Because of this, the sound produced was more varied due to the combination of engine, propeller and hydrodynamics. The variation in frequency produced by fishing vessels 10 GT was caused by the larger size and tonnage of the boat. Therefore, the frequencies produced by each source (engine, propeller and hydrodynamics) were also more varied.

Noise intensity. Figure 1 shows further differences in noise intensity for each variety of traditional fishing boats. Generally, the changes in intensity vary based on the ship's type and movement (Fig. 1, left). Following the waveform recorded by the receiver, the intensity increases since the noise was detected. In addition, it reaches the peak when in the closest distance with the receiver, and then decreases as the ship moves away. Despite having the same pattern, the intensity and rate of change differ between one type of vessel to another. These include the highest receive level and the increased change pattern of noise intensity seen on 3 GT fishing boat (Fig. 1A, left). This is inseparable by the speed of the ship and higher than others since the intensity of the source level was also high. The rapid movement of the vessel as a consequence of such speed causes the distance with the receiver to change rapidly. The longer the distance of the ship with the receiver, the lower the intensity due to the presence of sound absorption, which may lead to increased transmission loss. Furthermore, similar reason was also directed to 5 and 10 GT fishing boats, where noise intensity also changes based on recording time due to changes in distance (Fig. 1B and 1C, left). The 5 GT fishing boat had a slower change in intensity even though the speed is higher than that of 10 GT. This is because the source level is lower as a result of decreased engine power that complements the ship.

Figure 1 (right) shows the changes in receive levels of fishing boat noise for each frequency (1, 5, 10, and 15 kHz) based on the distance. Generally, it had the same pattern at the recording time changes as a consequence of distance. However, the intensity of noise clearly seen is different when the ship approaches the closest distance to the receiver. Receive level for noise frequency of 1 kHz was not much different from 5 kHz. Therefore, the noise frequency of 10 kHz was similar with 15 kHz in both 3, 5 and 10 GT fishing boats. The noise frequencies up to 5 kHz can be detected well by receiving levels above 135 dB re 1 μPa. Meanwhile, the receive level above 10 kHz were below 135 dB re 1 μPa. As the ship move away from the receiver, there was no significant intensity difference for each frequency. This is because the existing receive level was a combined intensity of broadband frequency.

The noise changes of each frequency as a function of distance for 3 GT fishing vessels are shown in Fig. 1A (right). At the closest distance (42.6 m), the receive level was the highest intensity (153.0, 138.9 and 135.7 dB re 1 μPa for frequency up to 5,10 and 15 kHz respectively). As the vessel moves away 52.7 m (10 s), the noise intensity decreases proportionally for each frequency. The decrease continues to occur when it moves away to 75.2 m (20 s), the receive level was the intensity of the broadband frequency with ranges to 114.6 dB re 1 μPa. Different intensity changes were shown by 5 GT fishing boat, where receive levels did not have significant changes to a distance of 57.5 m (20 s) with an intensity of 138.1 and 127.7 dB re 1 μPa for frequency up to 5 kHz and above 10 kHz respectively (Fig. 1B, right). Meanwhile, a significant decrease was seen as the ship's distance continues to drift away where the intensity of sound is a combination of broadband frequency. Changes in the same pattern occurred at 10 GT fishing boat, where intensity changes were seen when the vessel stayed away for 20 s (61.8 m), as shown by Fig. 1C (right). The difference in noise intensity changes for each of these frequencies showed that variations in ship size, engine's type and power, and operational speed affect the source level and transmission loss of noise.

Noise spectra. Figure 2 shown the fishing boat noise spectra based on the ship's travel time which represents the distance. Spectra noise appears to vary based on the type of fishing boat, where the frequency of 3 GT had a wider range and experiences faster loss of spectra based on distance compared to the 5 and 10 GT (Fig. 2, left). However, the frequency had increased quadratically based on the distance, and the pattern of settlement varies. This variation was due to differences in the source frequency and operating speed, ship types and engines. The smaller 3 GT fishing boat, which is equipped with a 20 HP gasoline-fueled outboard engine can be operated at a higher speed, influencing the spectra noise to be produced in wider broadband frequencies and disappear faster with recording time (Fig. 2A, left). Also, 5 and 10 GT fishing boats, which are both equipped with a diesel-fueled outboard engine, have the same spectra pattern. Small differences may be observed in the frequency range and the increasing pattern based on the distance, where the 5 GT fishing boat has a smaller range and the change pattern is slightly larger than the 10 GT (Fig. 2B dan 2C, left). This occurs due to differences in engine power and operational speed of the two types of vessels.

Figure 2 (right) shown a further change in frequency for each vessel based on distance. Generally, the group (< 1, 2–3, and > 4 kHz) experienced a quadratic increase along with the recording time, which represented distance. The higher the frequency, the clearer is the reduction pattern for the three types of fishing vessels. In 3 GT, the frequency changes were seen to be lower in the < 1 kHz group, with a quadratic coefficient of 0.0008 (Fig. 2A, right). On the contrary, the pattern of increasing frequency slightly changed in the 2–3 kHz group, where the quadratic coefficient increased to 0.0009. The changes were observed in the higher group, where the coefficient was above 0.0252 when the noise frequency was > 4 kHz. Even though it had the same tendency, the quadratic coefficient of increasing frequency was lower on the 5 GT fishing boat (Fig. 2B, right). In the same frequency group, the quadratic coefficients for this type of vessel only ranged from 0.0002, 0.0003 and 0.0012, respectively. This value was still higher than the quadratic coefficient for each group produced by 10 GT fishing boats, were 0.00002, 0.00009 and 0.0020 belonged to the frequency group of < 1, 2–3, and > 4 kHz, respectively. Therefore, the variation of the source frequency as a representation of ship and engine type, as well as operation speed influenced differences in receive frequency and change patterns.

Discussion

The very high potential of fishing in Cilacap waters with a variety of resources has been a particular incentive for local fishermen to optimize them as a source of income. The occurrence of illegal fishing, which has increased dramatically in Indonesian waters, has posed a threat to fisheries management[3]. The condition also forces fishermen to increase the number of fishing fleets and compete in utilizing existing resources. Technological limitations required them to use makeshift in the form of traditional boats for fishing[1].It was operated with a machine and was equipped with simple fishing gear[5]. This traditional fishery management was conducted by the local government based on the community which was in line with the decentralization of policies[2]. Therefore, there is need to address an ecosystem approach to fisheries management (EAFM) as an effort to use sustainable resources[4].

The increase in the number of traditional fishing boats with the aim of optimizing the use of fisheries resource has its own implications. Different types of vessels with various sizes, engine types and operating speeds contribute to the variation in the underwater noise produced. The 3 GT fishing boat 3 equipped with a gasoline-fueled outboard engine dominated the effort in these waters. It can produce noise with a wider frequency range and a higher intensity compared to other types. This is because the type of engine used was a 2-stroke with high cavitation, which results in higher noise than other types with the same power[13,14]. Furthermore, small ships produce higher noise because they are equipped with high-speed engines and propellers[31]. Despite having lower spectral levels, 5 and 10 GT fishing boats also contribute to environmental noise in the waters. On the contrary, larger vessels produces low frequency noise due to lower engine and propeller RPMs[7]. These difference are closely related to the speed, size and load of the ship[50], type of engine, propulsion system and propeller[51], and the sound mechanism[52].

The noise characteristics of these three types of ships changed based on the distance, frequency and intensity since the spectra can still be heard at a certain distance. Sound intensity decreases based on distance when propagating[7,37,53]. It is related to the aquatic medium which can absorb sound and the coefficient depends on frequency, temperature, salinity and depth[54,55]. In contrast to intensity, the frequency had increased due to changes in the position of the ship and the receiver when is operated[56,57], as a consequence of the doppler effect[58]. The existence of noise with certain characteristics and can even be detected at certain distances generated by the traditional fishing boat. This has the potential to threaten the existence of marine life, both fish and mammals. Some of the threats from ship noise to biota were in the form of behavioral disturbances, physical damage, and even causing death[34].

Previous studies on aquatic biota (see [9–15]) shows the existence of a traditional fishing boat in the waters of Cilacap should be managed in such a way that the available resources remain sustainable. Several countries and regions have formulated regulations regarding the limits of noise which allowed for shipping making operating vessels to comply with these regulations. Several international agreements that are concerned with underwater noise impacts were the European Union (EU) Marine Strategy Framework Directive (MSFD), International Whaling Commission (IWC), Convention on the Conservation of Migratory Species of Wild Animals (CMS), Arctic Council's Protection of Arctic Marine Environment (PAME), International Maritime Organization (IMO), Helsinki Commission (HELCOM), OSPAR Commission (OSPAR), International Union for the Conservation of Nature (IUCN), Convention on Biological Diversity (CBD), and UN Oceans Resolution[59]. Unfortunately, the relevant regulations are not regulated in Indonesian waters, so fishing vessels can operate freely without binding monitored. When this continues, it was predicted that the presence of marine life in the waters will be increasingly threatened along with the increasing use of ships as a main for marine transportation. As a follow-up, it was necessary to conduct comprehensive study related to the sound of ships both fishing and other commercial vessels and their impact on marine biota as an initial effort to mitigate noise pollution in Indonesian waters.

Declarations

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Figures

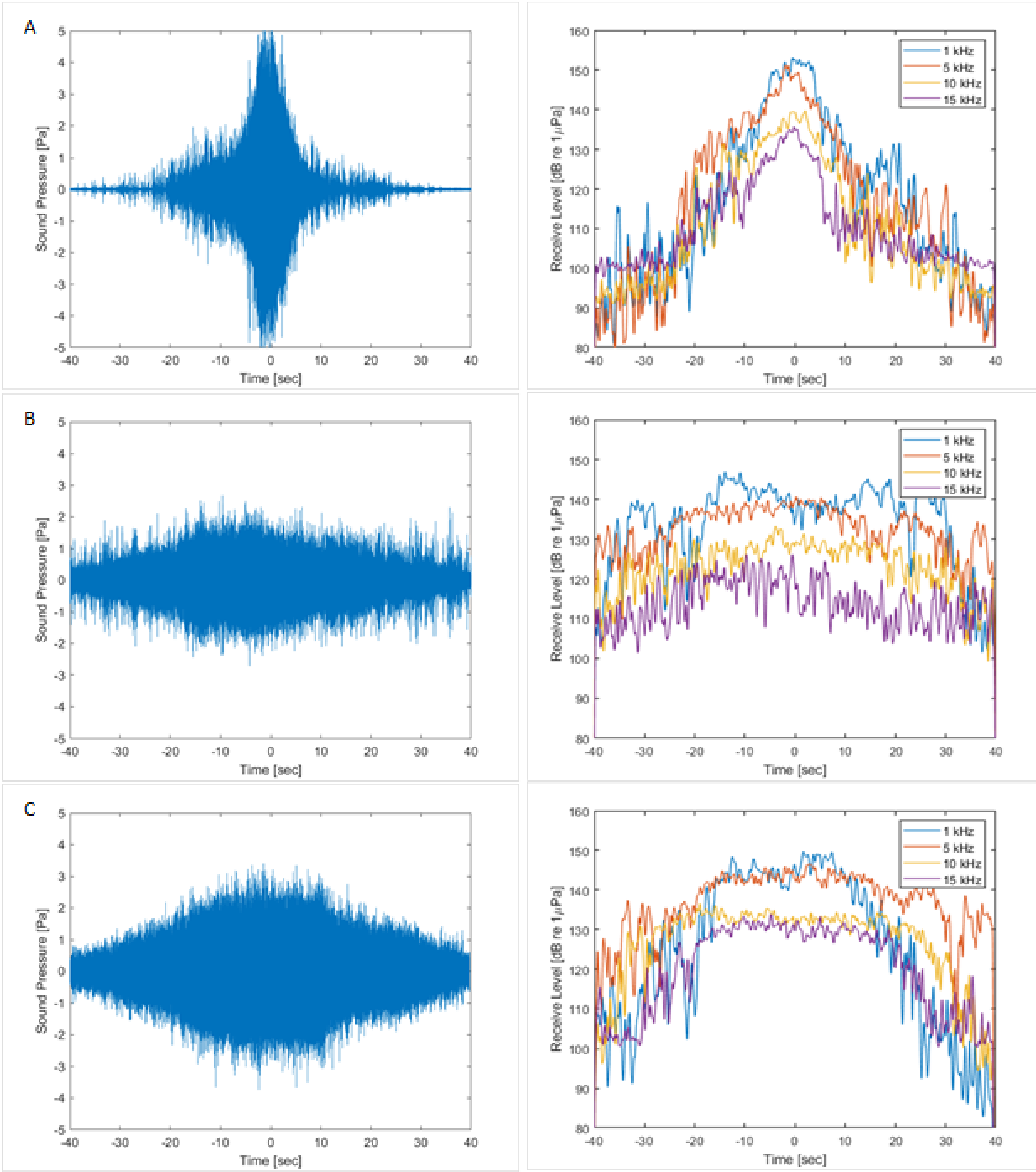

Figure 1

Noise intensity of traditional fishing boats; sound pressure level (left) and receive level for certain frequencies (right). (A) – (C) represent to 3, 5, and 10 GT respectively.

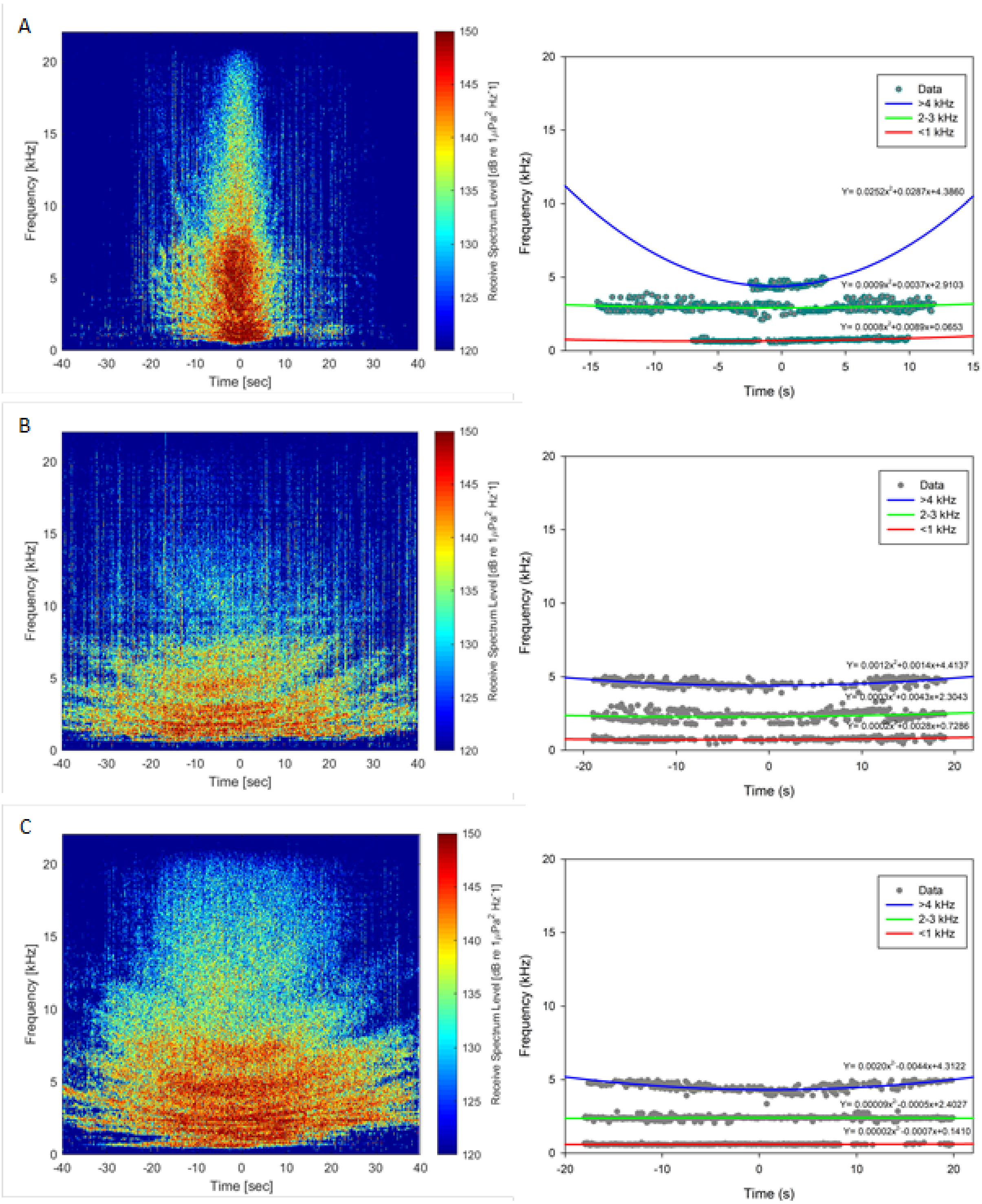

Figure 2

Noise spectral of traditional fishing boats. (A) – (C) represent to 3, 5, and 10 GT respectively.

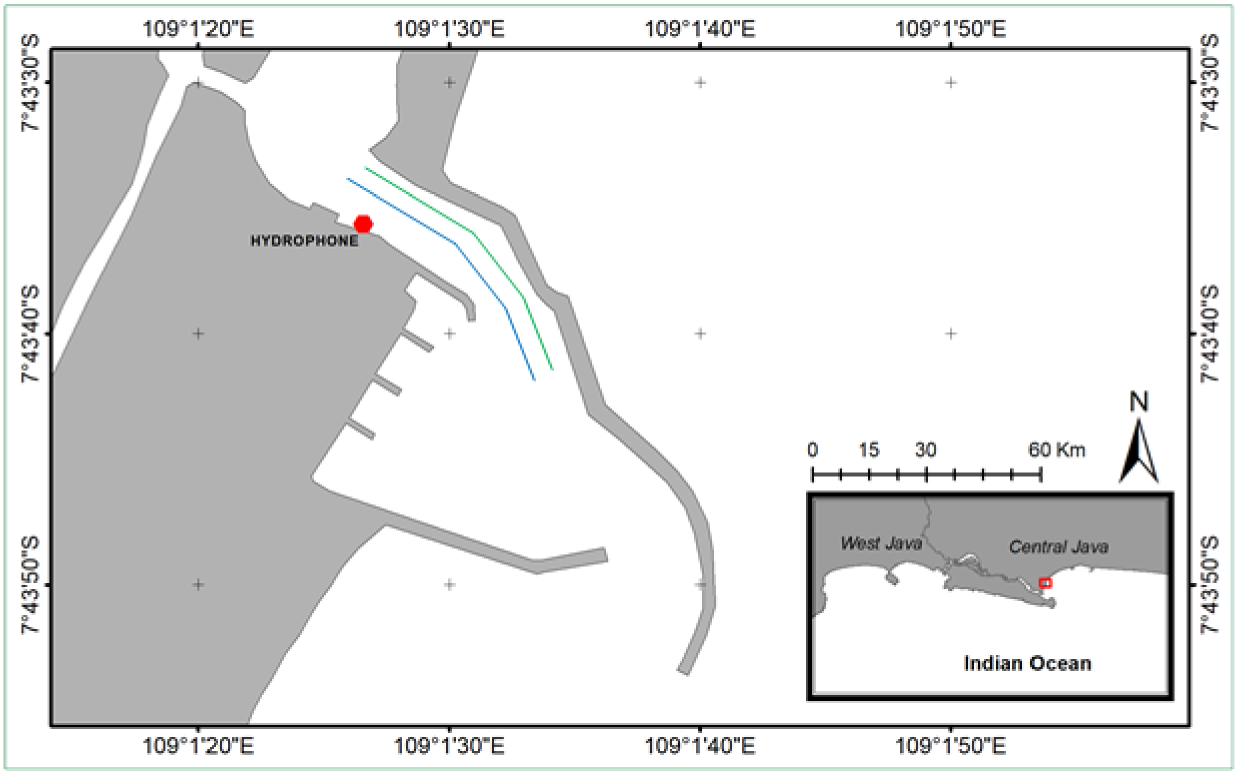

Figure 3

Recording's site. Solid lines represent to inner lane (blue), and outer lane (green). Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.