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Sound Productivity of Spiny Lobster *Panulirus homarus* (Linnaeus, 1758) due to Crude Oil Contamination: The Basic of Bio-acoustic Identification for Water Quality Purposes

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ABSTRACT

Anthropogenic activities including crude oil have the potential to put pressure on the marine environment, giving rise to the responses of aquatic organisms, such as sound. This study aimed to analyze the sound productivity of spiny lobster *Panulirus homarus* (Linnaeus, 1758) in waters contaminated with crude oil. The lobster sound was observed on a laboratory scale using the passive acoustic method. Furthermore, a hydrophone and Closed Circuit Television (CCTV) camera coupled with a decoder and personal computer were used to record the movements and sounds of *P. homarus* during the treatment of crude oil at concentrations 0; 1; 5; 10; and 100 mgL^{-1}. Observations have been carried out for 24 hours using a continuous method in changing of crude oil concentration. The crude oil contamination in water was impacted to the productivity of *P. homarus* and more sound was produced at a low concentration of crude oil (1 - 5 mgL^{-1}). The response of *P. homarus* showed significant differences between individuals until it reached a concentration of 10 mgL^{-1}. At 100 mgL^{-1} concentration, sound productivity of all lobster were decreased.

Keywords: *Panulirus homarus, crude oil, fish sound*

ABSTRAK

Aktivitas antropogenik, termasuk minyak mentah (*crude oil*) berpotensi memberikan tekanan pada lingkungan laut, sehingga menimbulkan respons organisme akuatik, seperti suara. Penelitian ini bertujuan untuk menganalisis produktivitas suara Lobster Pasir *Panulirus homarus* (Linnaeus, 1758) di perairan yang tercemar *crude oil*. Suara lobster diamati pada skala laboratorium menggunakan metode akustik pasif. Selanjutnya, sebuah hidrofon dan kamera Closed Circuit Television (CCTV) yang digabungkan dengan *decoder* dan komputer digunakan untuk merekam gerakan dan suara *P. homarus* selama perlakuan *crude oil* pada konsentrasi 0;1; 5; 10; dan 100 mgL^{-1}. Pengamatan dilakukan selama 24 jam dengan perubahan konsentrasi *crude oil* secara berlanjut. Kontaminasi *crude oil* dalam air berpengaruh terhadap produktivitas *P. homarus.* Suara lobster dihasilkan lebih banyak pada konsentrasi *crude oil* rendah (1 - 5 mgL^{-1}). Selanjutnya, respon suara *P. homarus* menunjukkan perbedaan yang nyata antar individu hingga mencapai konsentrasi 10 mgL^{-1}. Pada konsentrasi 100 mgL^{-1}, produktivitas suara seluruh lobster menurun.

Kata kunci: *Panulirus homarus*, *crude oil*, suara ikan

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1. Introduction

Several anthropogenic activities such as offshore mining and sea transportation can put pressure on the marine environment. One of the pollutants produced from these activities is crude oil and its contamination is a global problem that has a negative impact on the environment (Khan et al., 2018). The main component of crude oil is very toxic to some organisms (DeFoe & Ankley, 2003; Gerdes et al., 2005), and the effect of its pollution on marine life is also a world issue and has been widely studied. According to Perrichon et al., (2021), the toxicity of crude oil affects the early stages of *Hippoglossus hippoglossus* (a species of fish) embryonic development in Atlantic waters. In addition, Yuewen & Adzigbli, (2018) discussed the impact of oil spills on

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marine biota, citing habitat destruction, mass mortality, impaired physiological functions such as reduced feeding, growth and development, respiratory problems, loss of motion, balance, and swimming as the effects of lethal to sub-lethal doses of Poly Aromatic Hydrocarbons (PAHs). Incardona et al., (2014) also reported that *Oncorhynchus gorbuscha* showed a stunned reaction, slow and low movement, loss of stability and balance, melanosis, and inconsistent swimming when contaminated with crude oil. Meanwhile, Versluis et al., 2000; Price & Mager, 2020 stated that fish response to crude oil contamination was the failure of their swim bladder during development, which is caused by inflation, specifically during the early stages of life.

Changes in behavior have a significant effect on the sound production of marine organisms. According to Kasumyan (2009), sound plays an important role in fish behavior, including reproduction, movement, aggressiveness, and feeding. Furthermore, fish sound production plays an important role in studying behavior, because the activities of fish in the water are difficult to observe and study. Carriço et al., (2020) also stated that it is an important component in the dynamics of deepwater biodiversity. Colleye et al., (2019) investigated the acoustic signal of *Porichthys notatus* and its significance in the breeding process. Amron et al., (2017) stated that changes in water temperature have a potential impact on fish behavior, which is represented by productivity and sound characteristics.

Passive sonar is one of the methods developed to observe the acoustic response of fish sounds. Meanwhile, passive acoustics is an act of listening to sound waves emanating from various objects in the water column, usually sound received at a certain or specified frequency for various analyses. It is becoming a popular tool determining the temporal and spatial localization of spawning properties of fish populations that actively generate cells to attract mates in spawning (Fine & Thorson, 2008). This method with hydrophones has been used as a very effective and harmless instrument to observe fish behavior and orientation (Gilmore, 2002).

The observation of fish behavior with a passive acoustic system can be conducted by utilizing the sound they produce (Mann & Lobel, 1995). Several studies described the sound of fish in relation to their activities and most were found to produce sounds with specific characteristics while spawning (Lobel, 1992; Tricas & Boyle, 2015). The male and female *Pempheris schwenkii* emit a series of sounds 2-7 times, with a duration of about 56 ms, and a sound frequency of 100 Hz with 2 rhythms that occur when the fish experiences an expression of fear (Takayama et al., 2003). During the reproductive season, male opsanus tau produces a sound such a strong ship whistle for an extended period such that it is heard and approached by the female fish (Popper & Platt, 1993). According to the analysis of Rountree et al., (2002), sound functions in communication during the spawning season in several species and is a useful attack or defense mechanism. In some cases, they produce friction sound using their fins to scare away predators and also to protect their nest. Kang et al., (2017) was identified the alternations in sound characteristics of *Oryzias latipes* due to toxicants exposure.

Studies on the sound of marine life have also been carried out on spiny lobster (*Panulirus argus*). This species makes sound during stridulation by moving the two antennas quickly toward the rostrum file (Mulligan & Fischer, 1977). It was further explained that one movement of the antenna will produce a *squeaking* sound composed of pulses with varying duration for each individual. An extended duration is due to the longer carapace of the lobster and a *slow rattle* sound is made by the mouth and not the friction of the antennae.

The phenomena of sound and behavior mentioned above show that it is a part of marine life. However, the detection of noise associated with the presence of contaminants, especially crude oil, has not been widely carried out. It is essential to investigate the characteristics and sound productivity of marine biota in response to crude oil contamination for monitoring water quality at different dimensions.

2. Materials and Methods

This study adopted the experimental methods on a laboratory scale. Three male spiny lobsters (*Panulirus homarus*) with a total length of 12 cm, weight 105 grams, carapace width 3.5 cm and carapace length 6 cm in average were used in this study. Lobsters were caught by fishermen in the Cilacap Waters, Central Java, Indonesia, and transported to the Marine Acoustic Laboratory of Fisheries and Marine Sciences Faculty, Jenderal Soedirman University. Before being observed, lobsters were acclimatized for two weeks to ensure that they adapt to their new environment.

A hydrophone and two cameras were installed in an aquarium with dimensions of 60 cm × 25 cm × 30 cm, filled with 36 liters of

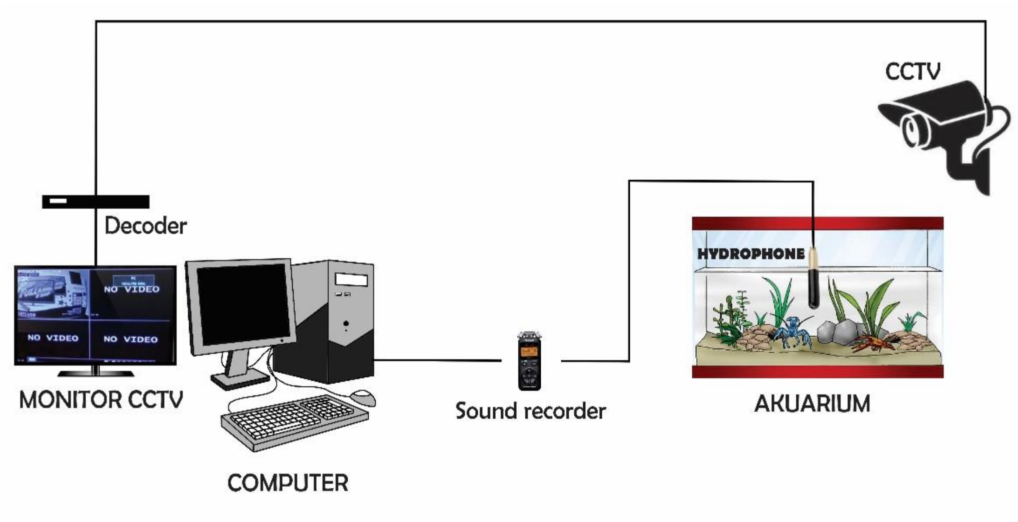

Figure 1. Acoustic Instrument Design of *P. homarus* sound

seawater (32 ppt of salinity) and connected to a voice recorder and computer, following a modified experimental design Jézéquel et al., (2020) (**Figure 1**). Crude oil has been obtained from oil refinery PT. Pertamina Cilacap with a relative density 0.8 to 1.0 and water solubility 1 to 2% according to Safety Data Sheet Number 888100008800.

Observations have been carried out for 24 hours using a continuous method in changing of crude oil concentration. Crude oil concentrations of 0 mgL^{-1} (control); 1 mgL^{-1}; 5 mgL^{-1}, 10 mgL^{-1}, and 100 mgL^{-1} as treatments with three replications and single specimen for each treatment (**Figure 2**). That concentrations based on Indonesian government standard which the maximum concentration of crude oil on the sea organism tissue was 1 mgL^{-1} and the maximum concentration on the sea water was 5 mgL^{-1} (Indonesian Government Regulation No. 22, 2021). Meanwhile, the other concentrations (10 and 100 mgL^{-1}) were treated to give the extreme condition.

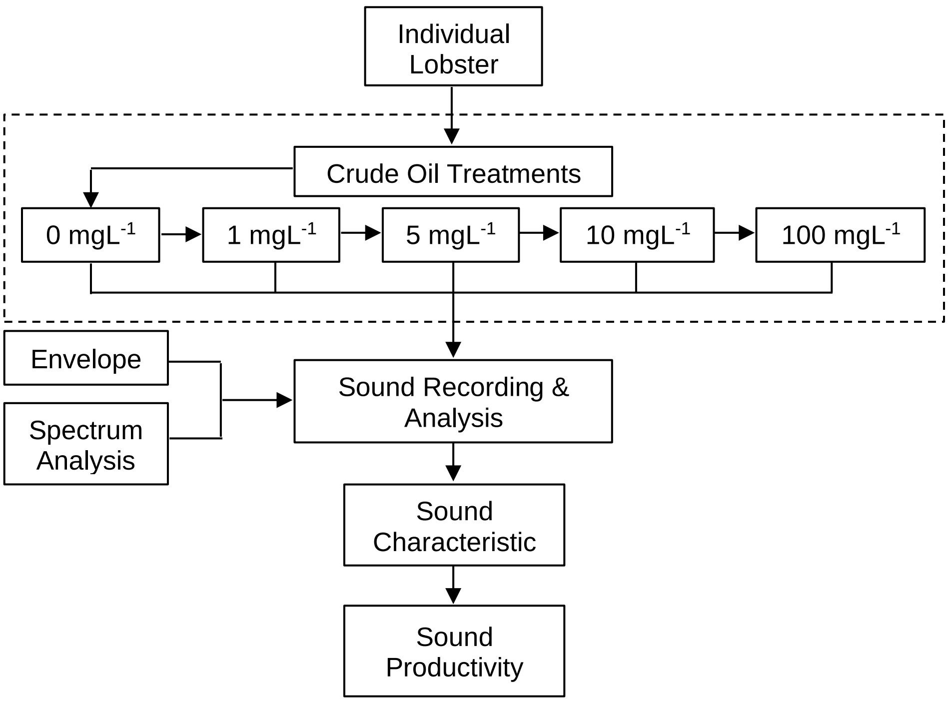

Figure 2. Sound Productivity of *P. homarus* Experimental Design with Crude Oil Treatments.

The determination of sound productivity begins with listening to all recordings and was carried out after the completion of the envelope process and spectrum analysis. The desired sound and noise in the recorded data should be separated before analysis. The steps taken include envelope, spectrum analysis, sound characteristic, and the number of sound produced within 24 hours in water. Furthermore, the average sound production of *P. homarus* was analyzed to determine the type and daily productivity of lobsters. Data were analyzed using the Kruskal-Wallis test.

3. Result and Discussion

There were four types of the sound of *P. homarus* sound observed in this study, namely *popping*, *squeaking*, *slow rattle,* and *rasp* sound. The sound produced by lobster are categorized into the movement of file and plectrum organs with a slip and stick mechanism (The *rasp* and *slow rattle*) and movement of claw organs (*popping*) (Mulligan & Fischer, 1977; Patek, 2001). The types of sound were determined by their characteristics such as pressure, duration, and frequency. Overall, the sound of *P. homarus* characterized by pressure 77 – 145 dB re 1 µPa, sound duration below 449 ms and sound frequency 4 – 20 kHz (**Table 1**).

The sound productivity fluctuated with changes in crude oil concentration. **Table 2** shows the observation data of lobster sound production for 24 hours with crude oil concentration treatment. The results showed that *P. homarus* produced more sound when exposed to low crude oil concentration (1-5 mgL^{-1}). Based on the normality test result, the number of sounds produced by the species at a concentration of 1 mgL^{-1} was normally distributed. Kruskal Wallis showed that at varying crude oil concentrations, the production for each type of sound was not significantly different. The response of *P. homarus* showed significant differences between individuals until

Table 1. Characteristics of *P. homarus* sound types

Type of Sound	Pressure (dB re 1 µPa)	Duration (ms)	Frequency (kHz)
Popping	125-140	below 100	4-20
Squeaking	77-101	25-449	6-18
Slow rattle	135	below 100	10- 19
Rasp	130-145	100-400	10- 19

Table 2. Sound productivity of *P. homarus* in different concentration of crude oil

Crude Oil Concentration	Sound Productivity (in 24 hours)			
	Popping	Squeaking	Slow rattle	Rasp
	3	5	4	0
0 mgL^{-1}	4	3	1	0
	6	2	5	0
	5	0	0	0
1 mgL^{-1}	38	5	5	2
	6	2	6	0
	42	5	1	0
5 mgL^{-1}	26	1	4	3
	1	1	4	0
	12	7	0	0
10 mgL^{-1}	11	0	1	1
	3	0	2	0
	3	1	0	0
100 mgL^{-1}	3	0	0	0
	1	0	0	0

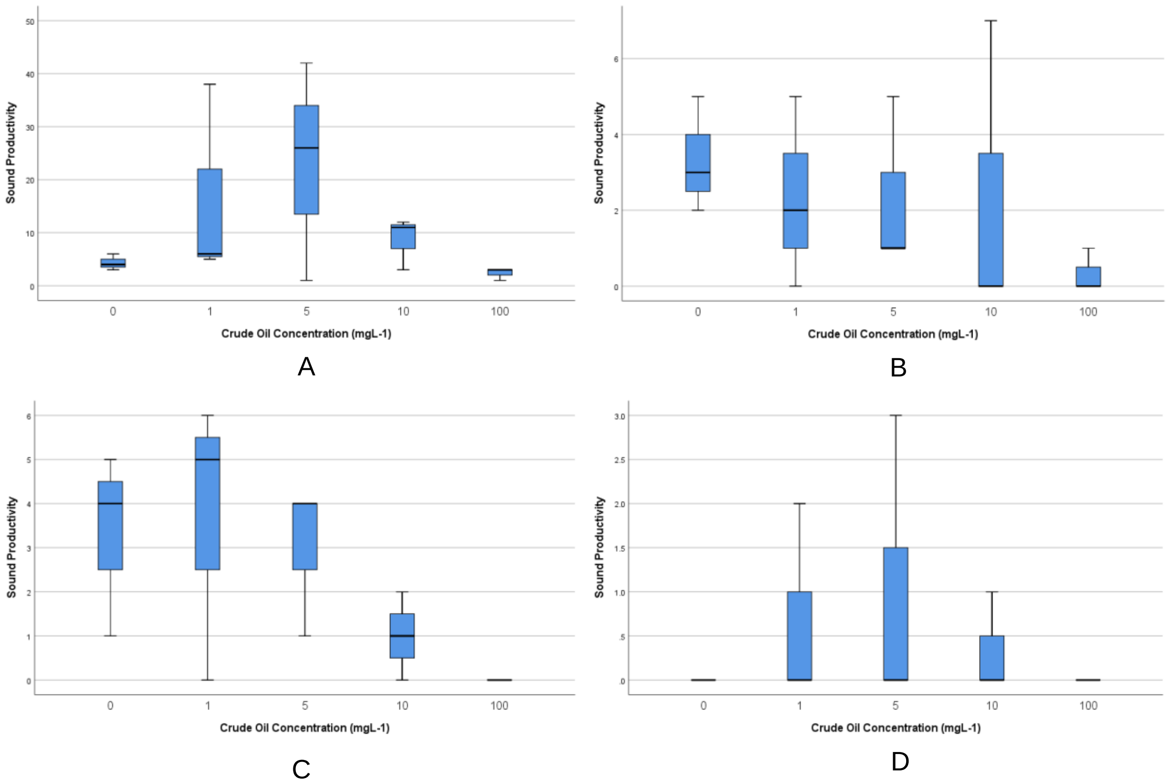

Figure 3. Statistical analysis of sound productivity of *P. homarus* (A. Popping; B. Squeaking; C. Slow rattle; D. Rasp)

the concentration of 10 mgL^{-1}. Furthermore, at 5 mgL^{-1} and 10 mgL^{-1}, the sound response produced was not normally distributed. Sound production also depend on the condition of *P. homarus* in facing the crude oil contamination. The sound production decreased until 100 mgL^{-1}, and in it concentration the response was constant and tended to be low for all sound types (**Figure 3**).

Fish can accumulate hydrocarbon compounds from crude oil and respond to environmental changes by adapting (Collier et al., 1995). However, crude oil is still one of the stressors in the aquatic environment that can evoke their response, which is in the form of behavior (Barton, 2002). When this stressor is too severe or lasts long inhibiting the fish's ability to regain homeostasis, then their health and life are threatened (Brown, 1993). The stress response can be in the form of endocrine, metabolic, and respiratory changes, as well as immunity, growth, disease resistance, and behavior (Barton, 2002). The sound made by fish provide useful information about their existence, distribution, and behaviours (Hamilton et al., 2019).

Based on sound's type, *popping* was mostly produced by *P. homarus* and it was mostly emitted until a concentration of 100 mgL^{-1}. However, its productivity decreased with increased crude oil contamination. This decreasing trend is also shown in other types of sound. *Popping* is also incidentally generated and produced by almost all lobsters and crustaceans through the movement of claw organs using the cavitation bubble mechanism with no specific behavior represented (Mulligan & Fischer, 1977; Hisyam et al., 2020). In some situations, cavitation bubbles occur due to crustaceans capturing or destroying their prey through claw movements (Versluis et al., 2000; Yang et al., 2020).

The sound mechanism production of spiny lobster associated with the movement of organs (Mulligan & Fischer, 1977). That organ movements indicated that the organism has identified crude oil as a threat and some emit sound in reaction to environmental changes (Bouwma & Herrnkind, 2009; Buscaino et al., 2011; de Vincenzi et al., 2021; Jezequel et al., 2018). In addition, the decrease in sound productivity presumed that *P. homarus* was under stress or pressure due to crude oil contamination. According to Barton, 2002, the stress response can be in the form of behavior change.

4. Conclusion

P. homarus observed in this study produce four types of sound, namely *popping*, *squeaking*, *slow rattle,* and *rasp* which determined by their characteristics such as pressure, duration, and frequency. Crude oil concentration significantly impacts the sound productivity of *P. homarus* and this was indicated by their response at the first introduction of the contaminant. Furthermore, the sound productivity decreased following an increase in crude oil concentration. Here, environmental changes caused by crude oil contamination impact on fish behavior, which is represented by productivity of sound.

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