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Short Communication

Sound Diversity as Representation to the Behavior of Spiny Lobster *Panulirus homarus* (Linnaeus, 1758)

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Abstract

Spiny lobster *Panulirus homarus* is one of many important economic fishery resources in Indonesia. Continuous exploitation activities in the natural habitat can potentially disturb the sustainability of lobster resources. This species is known to produce sound with certain characteristics and highly dependent on environmental changes. This study aimed to investigate the characteristics of sound as a representation of behavior. The sound produced by *P. homarus* was recorded for 24 hours using a hydrophone (a passive acoustic technique). The hydrophone converts the sound wave produced by the lobsters into electric voltage in millivolts, then were converted to a digital number, in order to be saved in a virtual format with the *.wav extension. The video system captured data on behaviors of resting, territoriality, aggression, and social attitudes. The results showed that *P. homarus* emitted rasp, slow rattle, and popping type of sound, with certain characteristics. All sounds types were characterized by a broadband frequency (4 - 20 kHz), and a source level ranging from 125 - 145 dB re 1 µPa. Rasp sound consisting of 12 - 40 pulses with a sound duration of 100 - 400 ms, represents a defensive behavior. Slow rattle sound with 2 - 7 pulses did not represent a specific behavior and it is dominant during the night. However, the popping sound with only one pulse represented feeding behavior.

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1. Introduction

Indonesia has many important economic fishery resources, one of them is Lobster (Petersen *et al*., 2012; Aslan *et al*., 2015; Wardiatno *et al*., 2016; Priyambodo *et al*., 2017; Akmali and Sari, 2020). Lobsters are widely exploited to meet high demand not only from domestic but also from foreign markets. Continuous exploitation activities in the natural habitat can potentially disturb the sustainability of lobster resources. In order to avoid sale of undersized lobsters, prohibition on lobster trade in Indonesian territory was implemented in the form of PERMEN-KP Number 56, which was published in 2016. This regulation contains some chapters about how lobsters caught should not be in a laying condition and the carapace length should be over 8 cm or individual weight over 200 grams.

One of the efforts to accommodate the high demand for lobster is cultivation (Aslan *et al* 2015; Priyambodo *et al*., 2016; Jones, 2010; Ton *et al*., 2020). The cultivation activities include catching the babies (post larvae), producing juveniles, and cultivating adult lobsters, with each activity having a separate business segment (Priyambodo *et al*., 2020). To support lobster cultivation activities and the sustainability of lobster stock in nature as well, an understanding of lobster behavior becomes important.

Lobster behaviour is represented by some kind of acoustic signaling. Some marine biota produce sound, including fish (Amron *et al*., 2017; Amron *et al*., 2018), and crustacean (Patek, 2002; Patek and Oakley, 2003; Henninger and Watson, 2005; Patek and Baio, 2007; Patek *et al*., 2009; Staaterman *et al* ., 2010 ; Buscaino *et al*., 2011a; De Vincenzi *et al* ., 2015; Jézéquel *et al*., 2018; Bouwma & Herrnkind, 2009; Jézéquel *et al*., 2020). The sound produced by these species provides important information about their existence, distribution, and behaviors (Hamilton *et al*., 2019). Most of the lobsters emits sound as means of protection from predators (Staaterman *et al*., 2010; Buscaino *et al*., 2011b; Ward *et al*, 2011) and response to the environment (Bouwma and Herrnkind, 2009). The main organs in lobsters producing this sound are the plectrum and file (Meyer-Rochow and Penrose, 1976; Cobb and Phillips, 1980; Henninger and Watson, 2005; Buscaino *et al*., 2011a; Fornshell and Tesei, 2017) through the stick and slip mechanism (Patek, 2001; Patek, 2002; Patek and Oakley, 2003; Patek and Baio, 2007). The sound produced by this mechanism is in the form of peak-to-peak source level which varies based on lobster size (Jézéquel *et al*., 2020), lower duration, number of pulses per signal, bandwidth, peak intensity, higher pulse rate, and frequency (Buscaino *et al*., 2011a). Another sound incidentally produced by lobsters with a different mechanism is the snap sound by the claws, through the use of the cavitation bubble mechanism (Hisyam *et al*, 2020). Generally, the sound of lobster produced by movement of file and plectrum organs with a slip and stick mechanism and movement of claw organs (Mulligan and Fischer, 1977; Patek, 2002).

Environmental changes are known to affect the sound characteristics produced by lobsters, as a form of their response. This study aimed to investigate the characteristics of sound as a representation of behavior.

2. Materials and Methods

2.1 Materials

Observation was conducted to spiny lobsters (*P. homarus*) caught along the coast of Cilacap (Central Java, Indonesia). A fiberglass tank with 1 m × 2 m × 1 m was used to acclimatize. Observation used two aquariums with 60 cm × 25 cm × 30 cm with 36 liters of salt water (32 ppt of salinity). Air pump (capacity of 2 × 4 L per min) and aerator 12 MP used to maintain the oxygen level. A hydrophone (type SQ-26) and CCTV camera (HD 1080p resolution and equipped with infrared light) were installed to record the sounds and movement of lobsters. Water quality was controlled using some equipment (pH meter, thermometer, DO meter, and hand refractometer). The lobster sound was analyzed by a free software named *Audacity* (Table 1).

2.2 Methods

2.2.1 Experimental design

Two individuals female (A and B) of spiny lobster *P. homarus* were observed in laboratory condition. Lobster A and B were 12 and 14 cm in total length, with 105 and 132 g in bodyweight, respectively. Before observation was conducted, lobsters were acclimatized for seven days, in order to adapt to their new environment. Both lobsters were reared in separate aquariums with lighting conditions in the laboratory adjusted to environmental conditions during the day and night, without additional illumination. The sounds produced by the lob sters were recorded using passive acoustic techniques, with hydrophone. The hydrophone converted the sound wave produced by the lobsters into electric voltage in millivolts. The electricity produced is still an analog signal which then converted into a digital signal, in order to be saved in a virtual format with the *.wav extension. The recording was conducted for 24 hours for each lobster. The video system (placed in front of the aquarium, as a CCTV camera) retrieved data on resting behavior, territoriality, and aggression. (Figure 1).

2.3 Data Analysis

The true sound of *P. humorus* was analyzed by basic detection algorithm that involved the following steps: filtering; rectify and envelope; smoothing; and gate (Mann and Lobel, 1995). Filtering done was band-pass filtering which limits the signal to certain frequency range where the fish call frequency is believed to be. Rectify and envelope were the absolute value of the hydrophone signal that effectively "traces" the outlines of the signal so that individual pulses can be detected. To describe sound of lobster in recording data, a smoothing step was conducted to get a true signal. The gate was used to identify the times when the processed signal went above a certain voltage.

Table 1. Research materials, specification and function

No	Materials	Specification	Function
1	Aquarium	60x25x30cm (length x height x width)	Lobster media
2	Fibber tank	1x2x1 m (length x height x width}	Acclimatization place
3	CCTV	HD 1080P, 2 MP CMOS Sensor	Behavior observation
4	Air pump	Capacity of 2 x 4 liters per mins	Water filter system
5	Aerator	12 MP	Oxygen supply
6	Hydrophone	SQ-26	Sound recorder
7	PH Meter	0,1 accuracy	pH observation
8	Thermometer	0,1° accuracy	Temperature observation
9	Hand refractometer	1ppt accuracy	Salinity observation
10	Software *Audacity*	Versi 2.3.3	Data analysis
12	DO Meter	DO-5510HA	Oxygen observation
13	Audacity software	Version 3	Sound analysis
14	Fish meat	Meat of *Trichiurus lepturus*	Lobster feed

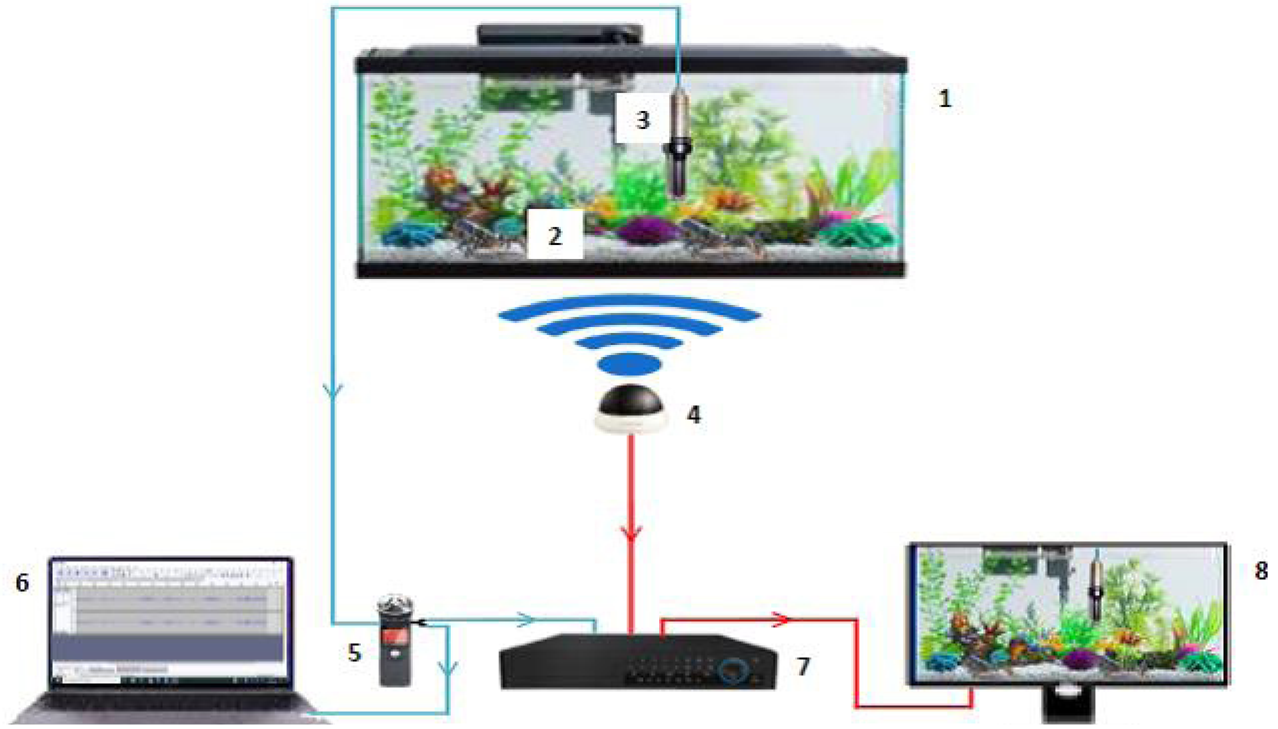

Figure 1. Recording systems. The blue and red lines represent the audio and video line (1–8) represented aquarium, lobster, hydrophone, CCTV camera, sound recorder, personal computer, video recorder, and LCD monitor, respectively

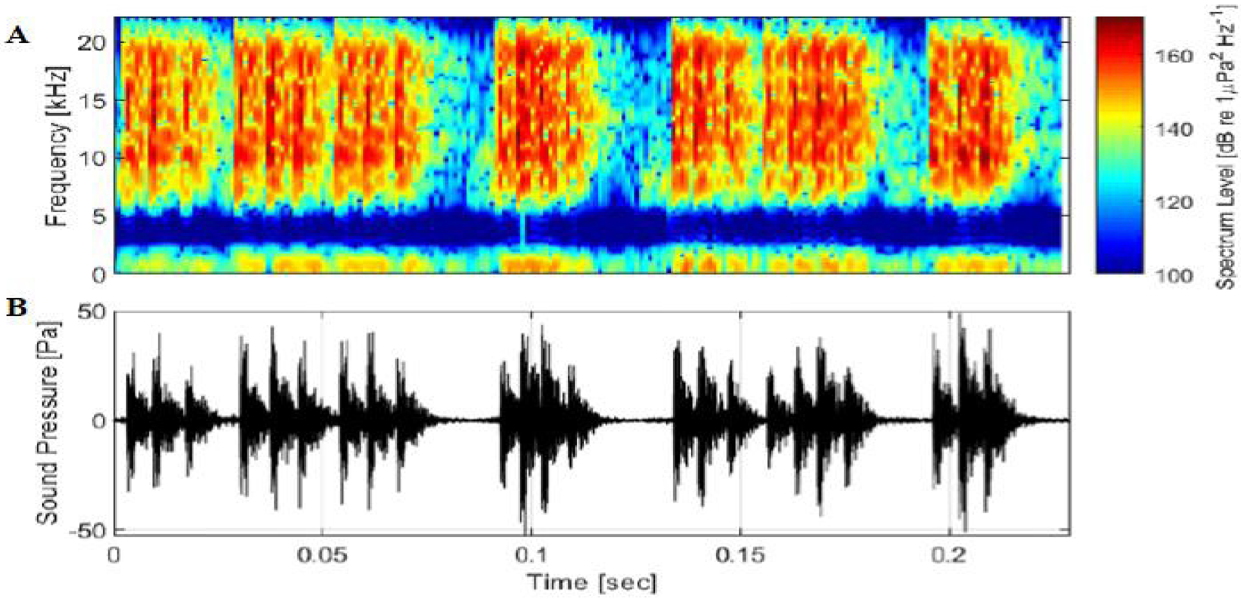

Figure 2. Sound characteristics of rasp; (a) spectrogram, and (b) waveform

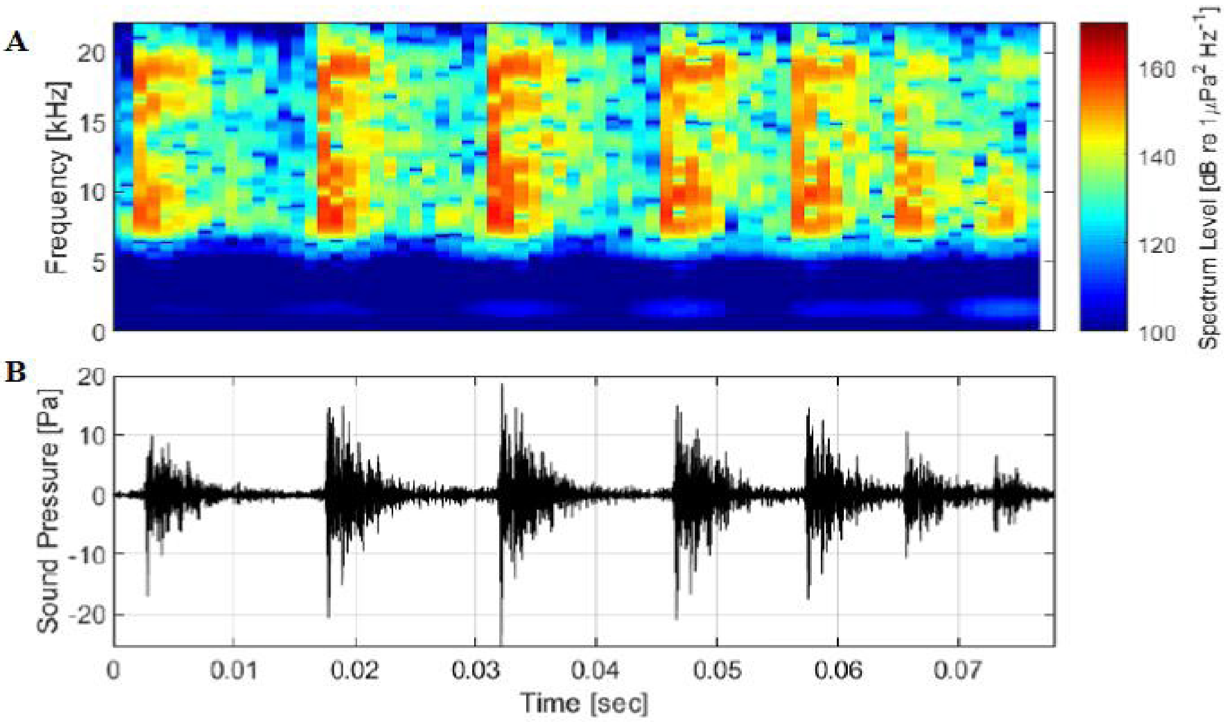

Figure 3. Sound characteristics of slow rattle; (a) spectrogram, and (b) waveform

3. Results and Discussion

3.1 Results

There were three types of sounds produced by spiny lobsters, namely rasp, slow rattle, and popping, which were distinguished based on the characteristics of the sound they produced. The contrast in sound characteristics was due to differences in the sound-generating organs and production mechanisms, which was a representation of their behaviors.

3.1.1 Rasp sound

Rasp sound was the most dominant noise issued by lobsters, containing more than a dozen and even up to 40 pulses (Figure 2). The sound series contained several groups of pulses, consisting of 2-4 rhythms for each class.

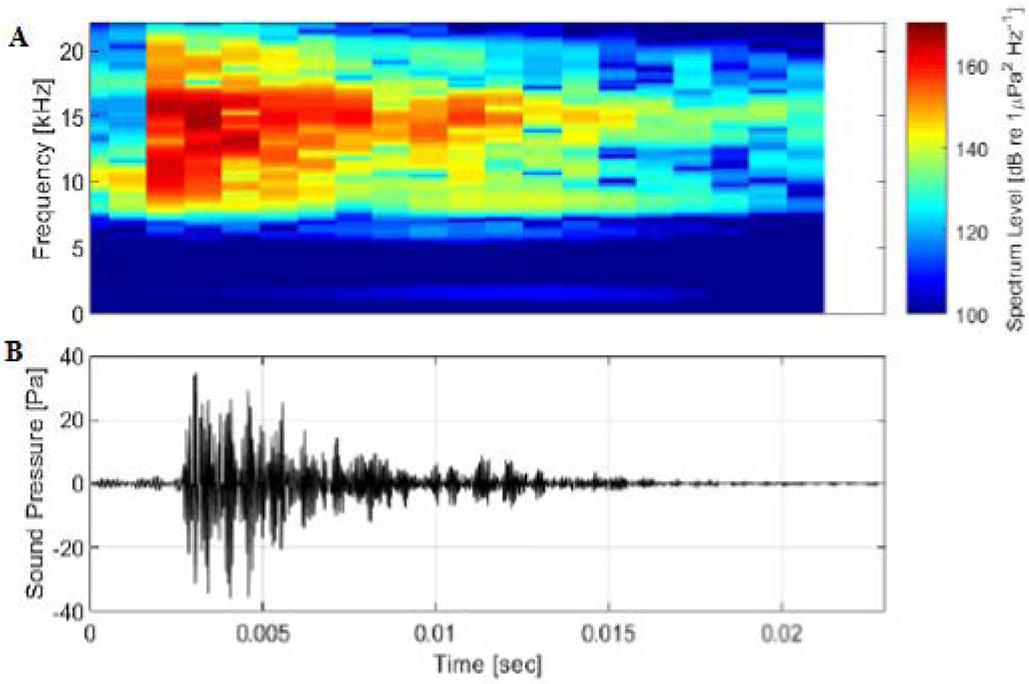

Figure 4. Sound characteristics of popping; (a) spectrogram, and (b) waveform

Pulses have specific characteristics of sound pressure, duration, and broadband frequency, ranging from 130-145 dB re 1 μPa, 100-400 secs, and 4-20 kHz, respectively. Also, the dominant frequency of each pulse was observed to be within the range of 10-14 kHz (Figure 2a). Sound pulses were characterized by a short duration (4-13 ms), as the interval period for each rhythm in the group was shorter than those in between the beat classes (Figure 2b).

3.1.2 Slow rattle sound

Similar to rasp sound, the slow rattle sound also contained series of sound pulses, which were characterized by a broadband frequency in the range of 4-20 kHz (Figure 3). While the number of sound pulse was generally more than a dozen for the rasp, the slow rattle had only 2-7 rhythms. The pattern of sound pulse series was also different for each type, as the slow rattle does not have rhythmic groups, compared to the rasp. This observation further indicated that there was no significant difference for the duration interval of each pulse (Figure 3b). At the beginning of the sound, the intensity of the pulse was relatively low, then increased with the next rhythm, reached a peak, and started to decrease. Moreover, a smaller number of pulses implied a sound duration of just below 100 ms. Slow rattle sound was also characterized by sound pressure, dominant frequency, and pulse duration, ranging from 125 to 135 dB re 1 μPa, 10 - 19 kHz, and 7-11 ms, respectively (Figure 3a).

3.1.3 Popping sound

Unlike rasp and slow rattle, the popping sound only had one pulse with a longer duration, which was 9-29 ms (Figure 4). This sound type also had a broadband frequency of 4-20 kHz, with a dominance ranging between 10-19 kHz (Figure 4a). Sound pulses have their own characteristics, starting with a higher intensity, and decreasing over the duration of the rhythm (Figure 4b). Also, the peak sound pressure of the pulse varied between 125-140 dB re 1 μPa.

3.2 Discussion

The rasp sound was formed due to the movement of a pair of organs (file and plectrum) with a slip and stick mechanism. This mechanism caused the sound produced to be in the form of a pulse series, which had a specific pattern. Generally, the organs of lobster that produced this sound were the plectrum and files (Buscaino *et al*., 2011a; Fornshell and Tesei, 2017). The plectrum is a springing device in the form of a striped pad, which bottom extends to the base of the second antenna. The file is the center of each antenna base (Cobb and Phillips, 1980). Lobsters produced sound by rubbing the two organs through a stick and slip motion (Patek and Baio, 2007). The sound was generated by rubbing each antenna against the receiver plate (Patek, 2002), as the friction medium of the stick and slip was like a stringed instrument (Patek, 2001). Another description related to this case was the contraction of the antagonist muscles, which were located at the base of the second antenna (Henninger and Watson, 2005). The duration of the mean pitch of sound was closely related to the length of the carapace, with the number and size of the spectrum (Meyer-Rochow and Penrose, 1976).

Rasp sound was a representation for lobsters against threats from predators or disturbances from the environment, both in the form of noise and movement. The number of sounds produced is highly dependent on whether the lobster is on alert due to the environmental disturbances. The number of sounds increased at night when it was dark due to being more sensitive to movement from the environment, which seemed like a threat to this species. The influence of the environment around the lobsters greatly affected the sound signals they produced (Patek *et al*., 2009). Predators of lobsters, such as fishes also affected the sound production of lobsters (Ward *et al*., 2011). This type of sound was a form of lobster defense strategy, during predator attacks (Buscaino *et al*., 2011b). Human activities also caused changes in behavioral responses and sound production of lobsters (Bouwma and Herrnkind, 2009; Staaterman *et al*., 2010). The response to stress due to acoustic stimulation, was another factor that affected the sound emitted by lobsters (De Vincenzi *et al*., 2015; Jézéquel *et al*., 2018).

The slow rattle sound type was not produced by lobsters as a representation of certain behaviors, as it only appears incidentally during rasp. The organ and mechanism of the sound produced was also the same as that of the rasp, namely the stick and slip medium of files and plectrum (Patek, 2001; Patek, 2002; Patek and Baio, 2007; Buscaino *et al*., 2011a; Fornshell and Tesei, 2017). This sound was produced simultaneously with a special rasp at night, by the movement of the antenna (Moulton, 1957). Generally, a slow rattle sound consisted of 6 - 10 pulses of well-damped clicks, with a duration of up to 100 ms, with each rhythm having a period of 12 ms (Meyer-Rochow and Penrose, 1976; Meyer-Rochow *et al*., 1982).

The popping sound type with certain characteristics was incidentally generated, when a lobster is eating. Generally, this sound is produced by almost all lobsters and crustaceans through the movement of claw organs. Although this sound was produced not as a representation of any specific behavior (Mulligan and Fischer, 1977), the specific organ producing it was the claw organs, using the cavitation bubble mechanism (Hisyam *et al*., 2020) . The occurrence of cavitation bubbles was due to crustaceans capturing or destroying their preys, through claw movements (Versluis *et al*., 2000). Therefore, this popping sound was closely related to the behavior of lobsters, when eating.

4. Conclusion

Spiny lobster (*P. homarus*) produces rasp, slow rattle, and popping sound. Each type of sound is characterized by different sound pressure, duration, and broadband frequency. These acoustic signals are related to the behavior of that species. Rasp sound represented a defensive behavior. Slow rattle sound did not describe any specific behavior, and is dominant during the dark period. The popping sound reflected the feeding behavior.

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Authors' Contributions

All authors have contributed to the final manuscript. The contribution of each author as follow, Hartoyo and Amron; developed the concept of manuscript, collected, analyzed, interpreted data, and visualized in graph and figure. Fitri and Darmanto; devised the main conceptual ideas and critical revision of the article. All authors discussed the results and contributed to the final manuscript.

Conflict of Interest

The authors declare that they have no competing interests.

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