Sound character of the coconut crab (*Birgus latro*) of Bacan Island

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Abstract. Coconut crab (*Birgus latro*) is a unique land living crustacea, that has economical value in some countries. While the abundance of crab in nature is very rare. The crab is nowadays being a protected organism. The study aims to determine the characteristics of sound produced by the coconut crabs. The data collection was conducted in November-December 2018. The sound was recorded in the new moon, using a microphone, TOA and recorder. Data of the sound was analyzed using software Wavelab, Matlab, and Excel. The sound type obtained by the coconut crab was snap sound that is used for repelling an opponent to came, and stridulating sound used for communicating. Male coconut crab producing stridulating sound to attract the female. The results of this study indicate that the snap sound had high frequency sound with a range of 400-500 Hz, but it was a high intensity sound. While the stridulating sound has a relatively high frequency with a range of 300-400 Hz, but low in its intensity.

Keywords: coconut crab; frequency; intensity; snap; stridulating

1. Introduction
Coconut crab (*Birgus latro*) is an animal that has high economic value, which is becoming rare in nature. This animal is included in the Redlist, which must be protected so that it does not become extinct [1]. In Indonesia, this animal is usually found in the eastern part of the Makassar Strait to Papua. These animals live on coral islands that have caved. Coconut crabs will come out and be found during the day, but if there are humans, coconut crabs will come out of their holes at night. During the day, these animals will hide in bushes and in the ground [2].

The crabs are animals that can adapt to both water and land ecosystem. These animals usually live in islands with rocky substrate and live in coastal areas close to the mainland and the coastal area [1]. The coconut crabs are animals that live in coastal areas and are more active at night in search of food [3]. During the day the crabs hide in order to avoid the sun.

The body of coconut crabs must be in a balanced state of salinity by drinking sea water all the time [4]. Thus, in the nursery there are containers of different salinity such as sea water and fresh water. The provision of sea water is intended for survival, while the provision of fresh water is to keep the body...
from becoming dehydrated. Coconut crabs have the aid of a breathing apparatus in the form of gills that surround the tissue like a sponge which is always moist, so that the coconut crab will wet its body into the water through its gills, which the crab can survive its survival [4]. Coconut crabs can survive for a long time on land because these animals first immerse their heads in water to wet the gill filaments for oxygen respiration which their gills can adapt to the gas exchange process [5]. These animals are ovigerous, and they carry fertilized eggs in their bodies [4].

Crustaceans are included in the category of three groups that have different sound characteristics with the sounds they produce [6]. The sound characteristics that occur are usually snap and stridulating sounds. Several researches on coconut crabs have been conducted by several researchers, including early studies of coconut crab captivity [7], local fishing and marketing activities [9], trial of coconut crab rearing [8], gonad maturity [10], reproductive biology [11], biology-ecology [12], reproductive migration [13], potential for adult-sized coconut crabs [14], habitat characteristics and growth patterns of coconut crabs [15], morphometric characteristics [16], spatial and temporal distribution of coconut crabs [17], and sex ratios and growth patterns [18]. However, the information related to animal bioacoustic has not been studied. This study aims to describe the sound characteristics produced by the coconut crab of the Bacan Island variety. This data is very important to distinguish the behavior and activities of coconut crabs from each different variety.

2. Method

2.1. Time and location
Data collection was carried out at the Fish Biology Eco-Laboratory, Ecobiology and Conservation Division of Aquatic Resources, Department of Aquatic Resources Management, Bogor Agricultural University, in November-December 2018.

2.2. Equipment and material
The materials used are 1 coconut crab (figure 1) with a carapace length of 11 cm, fresh water, sea water and feed (in the form of crab pellets) placed in a plastic storage box. The container is also equipped with a left-right hollow wooden box used for hiding places, a container for sea water and a container for fresh water that aims to breathe and keep hydrated. The details are listed in table 1.

![Coconut Crab (Birgus latro)](image-url)
Table 1. Equipment and materials used.

| Tools                      | Type          | Function                                   | Materials                          |
|----------------------------|---------------|--------------------------------------------|------------------------------------|
| Plastic Storage Box        |               | Rearing and food                           | One coconut crab                   |
| Small containers for sea water |               | Medium for coconut crab breathing and sea water | Sea water and fresh water         |
| Small containers for fresh water |     | Medium to keep the coconut crab from the dehydration | Freshwater                        |
| Perforated boxes           |               | Hiding place                               | PVC, brick stone, Coconut Shell and Fiber |
| Condensed Microphone       | TOA ZM -360  | Receiving the Crab’s sound 5Hz up to 20kHz | Electronic Instrument              |
| TOA Amplifier              | Meeting amplifier model WA -620 C | Amplifying the Crab’s sound               | Electronic Instrument              |
| Digital Recorder           | Sony ICD –PX470 | Recording the sound of coconut crab digitally | Electronic Instrument              |

2.3. Mounting the microphone/recording device on the housing

The container of 70 x 80 x 120 cm³, made of hard plastic materials was used for rearing the Crab. Two habitats were set-up for the Crab to live in, namely fresh water and seawater condition by providing two cups filled with sea water and freshwater. During the day the crabs hide in order to avoid the sunshine. The container was equipped with a resting place made of wood, coconut shell and fibre for the crab to hide during the day. Followings is the Experimental setting for coconut crab sound recording (figure 2).

Figure 2. Experimental setting for coconut crab sound recording.
2.4. Recording the crab’s sound
The Sound recording was conducted in November-December 2018 for about 2 months. A series of records was repeated for 4 times. The condense Microphone was suspended inside the rearing box, above the crab. The sound then amplified using TOA Amplifier before connecting it to SONY Digital Recorder. The sound data is then retrieved every morning. The sound data then converted to WAV form, in order to make them able to be analysed with Matlab and WaveLab (soundpost processing software). The Data then separated hourly to reveal the daily crab activity and sound produced.

2.5. Voice data analyzes
Sound Data editing was using Wave Lab 6.0. From hourly recorded sound, only the clear sound was collected. The sound the sliced for every 50msec. The selected sound then analysed to reveal its Sonogram (sound power in mV and in dB, against time) and to reveal the dominant sound frequency by converting the time domain data base to frequency domain data base using FFT (fast fourier transform). Those two results were used to reveal the sound character of Crab [19]. The sound threshold was set at -9dB from its maximum sound power [20, 21]. The Fourier transform is defined by the formula:

\[ S(f) = \int_{-\infty}^{\infty} s(t)e^{-j2\pi ft} dt \]

Note:
- \( s(f) \) = signal in the frequency domain
- \( s(t) \) = signal in the time domain
- \( e^{-j2\pi ft} \) = constant of the value of a signal
- \( f \) = frequency
- \( t \) = time

Two sound types were revealed, mainly Snap and Stridulating (figure 3). Voice data in FFT then analyzed Microsoft Excel.

![Figure 3. Comparison of waveforms sound from recording results (a) environmental conditions (b) sound snap and (c) sound stridulating.](image-url)
3. Result and Discussion

3.1. Result

3.1.1. Condition of coconut crabs. During the observation it was known that the Coconut crabs we used showed nocturnal activities. The crab was more active at night than during the day. The crab always hides in its hiding place during the day, but at night the crab came out of its hiding and was active crawling the observation box (figure 4).

![Figure 4. Condition of coconut crabs at night.](image)

3.1.2. Types of crab sounds. The crab produced snap and stridulating sound. Number of each sound per hour tended to be more during midnight. The Stridulating sound were much longer then snapping. The results of observation conducted on November 9, 2018 (Table 2), during the day, the Crab produced very rare sound. Mostly from 7 am to 6 pm the Crab tend to be quiet or no sound at all (table 2).

| Date            | Time       | Sound Type          | Repetition | Duration per sound block (ΔT) |
|-----------------|------------|---------------------|------------|-------------------------------|
| 9 November 2018 | 18.00-19.00| Snap                | 23 X       | 2.6 minute                    |
|                 | 19.00-20.00| Snap                | 28 X       | 1.65 minute                   |
|                 | 20.00-21.00| Snap and stridulating | 70 X    | 0.9 minute                     |
|                 | 21.00-22.00| Snap                | 38 X       | 0.84 minute                    |
|                 | 22.00-23.00| Snap                | 154 X      | 0.3 minute                     |
|                 | 23.00-24.00| Stridulating        | 19 X       | 1.4 minute                     |
|                 | 24.00-01.30| Snap and stridulating | 49 X     | 1.13 minute                    |
|                 | 01.30-03.00| Snap                | 56 X       | 1.18 minute                    |
|                 | 03.00-04.30| Stridulating        | 26 X       | 1.7 minute                     |
|                 | 04.30-06.00| Snap and stridulating | 43 X    | 1.05 minute                    |
|                 | 06.00-07.00| Snap and stridulating | 32 X     | 1 minute                      |
The snap sound frequency was around 100 Hz with sound intensity of $3.8 \times 10^4$ mV. The sound frequency range of 100-150 Hz and the duration length of 7-12 msec. Then the snap sound appeared again at 200-350 Hz, with a total duration of 1-12 msec. After that, appeared at 400 to 500 Hz, with a duration of 3 msec. and sound intensity of $6 \times 10^4$ mV. At the end was a short pulse 5 msec. with sound intensity of $3.5 \times 10^4$ mV (figure 5.)

Meanwhile, The Stridulating sound has several peaks. First at 100 Hz with 4000 mV, then 200 Hz at 29000 mV after that 700 Hz with 44000 mV, and 1000 Hz with 25000 mV (figure 6).

Figure 5. Power spectral density of snap sound.

Figure 6. Power spectral density of stridulating sound.
3.2. Discussion

The coconut crabs we used were more active at night similar to the observation of Rahman et al. (2016) [3] the nocturnal animal that looking for food at night particularly in the darkness. This crustacean is an organism that has different sound characteristics from the sound it produces [6]. The sound characteristics produced by coconut crabs (Birgus latro) are snap and stridulating sounds. Other sounds in the form of noise or noise have no function so they were not considered research data. According to Johnson et al. [22], noise in crustaceans is higher at night than during the day, a peak reached shortly after sunset and just before sunrise. The power spectral density graph of the snap sound produces different frequencies and intensities (figure 5). The yellow graph is a snap sound that has a high intensity value. The highest intensity is 6 x 104 mV and the lowest intensity is 0.1 x 104 mV. The highest intensity is yellow and the lowest is blue.

The snap sound functions are to keep predators away by electrocuting or killing prey animals that approach them [23]. In crustacean will not affect the snapping activity of the gun, but temperature will determine its distribution [24]. From the results obtained in this study, snap sound had a low frequency value compared to stridulating sound, but the intensity produced by snap sound was greater than stridulating sound. This was because the sound of a snap can makes a gun sound louder like a gunshot, while a stridulating sound makes a loud, repetitive sound. The snap sound is generated from the impact or friction on the cheliped joint, while the stridulating sound is produced due to the friction of the cilia and setae [25]. The sound produced in this animal has a function to survive its survival. The sound of snap was usually heard during the day and night [23]. When day and night there are predators coming, instinctively the coconut crab will sound a snap.

From the results of research carried out on November 9, 2018. The sound began with a continuous snap sound with a snap density per 2.6 minutes. The rate of sound released with the night. As it got closer to midnight the snap sound mixed with the stridulating, nearing midnight the test animals released an enormous amount of 154 x snap. Right at midnight the test animals did not snap to stridulating until morning. The test animals emitted stridulating sounds mixed with snap sounds (table 3).

Several research results related to the sound characteristics of aquatic biota have been carried out, including dolphin sound characteristics [26], and fish sound characteristics [27]. Research on the characteristics of crustacean sounds was also carried out by Field et al. [22, 28, 29].

The crustacean sound produced in the lobster sound Procambarus clarkii produces only snap sounds, it is different from research conducted on crustacean animals Birgus latro which can produce snap and stridulating sounds [29]. The snap sound carried out in Hisyam [29] research can produce freshwater crustacean crayfish Procambarus clarkii having a frequency range of 0.3-0.4 kHz. Meanwhile, in the research conducted [22] regarding the lobster crustacean Panulirus interruptus has a pincak value of 1.5-2 kHz. In contrast to the results obtained by coconut crab which has a frequency range of 400-500 Hz. Snap sound can produce sound with a frequency range of 0.1-200 kHz [21].

Power spectral density graph of -15 dB threshold on stridulating sound showed that crab produces stridulating sound had a higher frequency value than snap sound. Stridulating sound had a longer time because the sound produced from one sound to the next was produced long enough by the stridulating sound, so that the intensity obtained does not reach the maximum. The intensity was seen more clearly at a frequency of 300-400 Hz, this is because the stridulating sound produced by coconut crabs is heard more clearly at that frequency, so it has a high intensity value in the frequency section (Figure 7).

Based on research conducted on stridulating sounds [28], crustacean animals on the hermit crab have the lowest frequency value from <1000 Hz to the highest frequency of 6-8 kHz. The sound frequency obtained by the sound of coconut crab was from 300-400 kHz. It differs greatly from the results of the research obtained on the sound of coconut crabs. These have different sound frequencies because crustaceans had their own sound characteristics and the presence of factors such as differences in animal species, temperature, and behavior.

Several researcher regarding to semi-terrestrial crab, shown that they produce sound with a frequency in between of 1 Hz to 300Hz [30] that the Brachyuran living in mangroves area produces sound 40Hz.
up to 200 Hz), [31] 5Hz to 410Hz. Thus, the sound released by our *Birgus latro* was in a normal condition and not under stress.

4. Conclusions

Coconut crabs gave off a snap and stridulating sound. The snap and stridulating sounds released were influenced by time. In the afternoon, the sound of snap was more dominant, before midnight it changed to a stridulating sound and before morning there was a mixture of snap and stridulating sounds. The cause is need to explore more intensive.

References

[1] Sulistiono, Ibadillah, Vitas and Simanjutak C P 2009 Coconut crab (*Birgus latro*) seed production technology: coconut crab egg hatching *Prosiding Seminar Hasil-Hasil Penelitian IPB Bogor*: 533-548

[2] Haryanto and Wowor D 2017 Study of walnut crab population in Batudaka Island Togean Island Central Sulawesi and population management recommendations *J Biol Indones* 13(1): 149-156

[3] Rahman A, Ramli M and Kamri S 2016 Study of coconut crab (*Birgus latro*) in different habitats in the sub-district of Menui Island Morowali Regency *Jurnal Manajemen Sumber Daya Perairan* 2(2):153-159

[4] Abubakar Y 2009 *Study of biology as a basis for coconut crab* (*Birgus latro*) management on Yoi Island Pulau Gede District North Maluku Thesis Bogor (ID): Institut Pertanian Bogor

[5] Cameron J N and Meckklenburg T A 1973 Areal gas exchanges in the Coconut Crab Birgus Latro with Some Notes on *Gecarcoridea lalandii* Respiration *Physiology* 19: 245-261

[6] Simmonds E J and MacLennan D N 2005 *Fisheries Acoustics: Theory and Practice, 2nd edn.* Oxford: Blackwell Publishing

[7] Sulistiono, Refiani S, Tantu F Y and Muslihuddin 2007 Early studies of coconut crab (*Birgus latro*) breeding *J Akua Indones* 6(2): 183-189

[8] Sulistiono, Kamal M M and Butet N A 2009 Trial of coconut crab (*Birgus latro*) rearing in captivity *J Akua Indones* 8(1): 101-107

[9] Sulistiono, Kamal M M, Butet N A and Nugroho T 2009 Breeding activities and local marketing of coconut crab (*Birgus latro*) in Yoi Island North Maluku *Buletin PSP* 18(2): 65-71

[10] Sulistiono, Refiani S, Tantu F Y and Muslihuddin 2009 The maturity of coconut crab gonads in Saloso Island Central Sulawesi *J Akua Indones* 8(2): 175-184

[11] Refiani S and Sulistiono 2009 Morphological and histological structure of coconut crab gonads (*Birgus latro*) *J Ilmu-ilmu Perairan dan Perikanan Indonesia* 1: 1-6

[12] Supyan, Sulistiono and Riani E 2013 Habitat characteristics and maturity level of coconut crab gonads on the Island of Uta North Sulawesi *Jurnal Ilmu Perikanan dan Sumberdaya Perairan* 2: 73-82

[13] Sato T and Yosed K 2013 Reproductive migration of the coconut crab *Birgus latro* *Plankton and Benthos Research* 8(1): 49-54

[14] Supyan and Abubakar Y 2016 Study of the potential of adult sized walnut crab in the West Coast of Ternate Island North Maluku *J Techno* 5(1): 96-108

[15] Serosero R H, Suryani and Rina 2016 Characteristic and growth patterns of coconut crab (*Birgus latro*) in Ternate Island and West Halmahera, North Maluku Province *J Depik* 5(2): 48-56

[16] Serosero R, Sulistiono, Butet N B and Riani E 2018a Morphometric characteristics of coconut crabs (*Birgus latro* Linnaeus 1767) in North Moluccas Province Indonesia *AACL Bioflx Society* 11(5): 1616-1632

[17] Serosero R, Sulistiono, Butet N B and Riani E 2018b Spatial and temporal distribution of coconut crab (*Birgus latro* Linnaeus 1767) in Daeo Pullau Morotai North Maluku *Jurnal Ilmu Pertanian Indonesia* 23 (3): 211-219
[18] Serosero R, Sulistiono, Butet N A and Riani E 2019 Sex ratio and growth pattern of coconut crabs *Birgus latro* (Crustacea Decapoda Cianobitidae) in North Moluccas Province Indonesia *Omni Akuatika* 15(1): 1-11
[19] Demmerle A M and Karras T J 1966 Signal conditioning to improve high resolution processing for PFM telemetry NASA GODDARD space flifht center Washington DC Springfield Virginia: 24 page the genus trizopagurus *J mar biol* 67: 89-110
[20] Sipasulta R Y, Lumenta A S M and Sompie S R U A 2014 Simulasi Sistem Pengacak Sinyal Dengan Metode FFT *J Tekn Elek komp* 3(2): 1-9
[21] Lubis M Z, Pujjati S and Wulandari P D 2016 Passive acoustics for applications in fisheries and marine science *Oseana* 41(2):41-50
[22] Johnson M W, Everest F A and Young R W 1947 The role of snapping shrimp (Crangon and Synalpheus) in the production of underwater noise in the sea *Biol Bull* 93: 122-138
[23] Versluis M, Barbara S, Anna V D H and Detlef L 2000 How snapping shrimp snap: through cavitating bubbles *Science* 289: 2114-2117
[24] Patek S N, Shipp L E and Staaterman E R 2009 The acoustics and acoustic behavior of The California Spiny Lobster (*Panulirus interruptus*) *J Acoust Soc Am* 125(5): 3434-3443
[25] Burkenroad M D 1947 Production of sound by the Fiddler Crab Uca Pugilator Bosc with remarks on its nocturnal and mating behaviour *Ecology* 28(4): 458-462
[26] Lubis M Z, Pujjati S, Hestrianoto T and Wulandari P D 2016 Bioacoustic characteristics and behavior of male bottlenose dolphins (*Tursiops aduncus*) *J Teknol Perikanan Kel* 7(2): 179-190
[27] Pujjati S, Retnoa Ji B, Hananya A and Lubis M Z 2018 Pengamatan bioakustik pergerakan ikan sidat Anguilla sp dalam kondisi terkontrol (akuarium) *J Ilmu dan teknologi kelautan* 10(2): 467-473
[28] Field L H, Evans A E and Macmillan D L 1987 Sound production and stridulatory struc tures in hermit crabs of the genus Trizopagurus *Journ mar biol Assoc UK* 67: 89-110
[29] Hisyam M 2018 *Red Claw Crayfish* (*Cherax quadricarinatus*) *Sound Detection* Skripsi Bogor (ID): Institut Pertanian Bogor
[30] Boon P Y, Yeo D C J and Todd P A 2009 Sound production and reception in mangrove crabs *Perisesarma* spp. (Brachyura: Sesarmidae) *Aquat Biol* 5: 107-116
[31] Roberts L, Harding H R, Voellmy I, Bruintjes R, Simpson S D, Radford A N, Breithaupt T and Elliott M 2016 Exposure of benthic invertebrates to sediment vibration: From laboratory experiments to outdoor simulated pile-driving *Proceedings of Meetings on Acoustics* 27: 010029