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Note on Historical Records, Geographical Distribution, and Ecological Characteristics of a Mud Lobster, *Thalassina anomala* (Herbst, 1804) (Decapoda, Gebiidea, Thalassinidae) in Sarawak, Borneo

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ABSTRACT

The presence of mud lobster mounds is a common natural feature along coastal areas and tidal influence habitats in Sarawak. However, the number of species of mud lobsters that constructed the mounds is yet to be ascertained. This paper reviews historical records and geographical distribution of mud lobster in Sarawak from various forms of literature. The early records of mud lobster were from Buntal in Kuching, and Lingga in Sri Aman back more than 130 years ago. A few other records were reported from the central and northern regions of Sarawak between 1928 and 2019. All these records have identified mud lobster of Sarawak as *Thalassina anomala* (Herbst, 1804). Our present study at two sites in Buntal area with a careful examination of morphological characters of fresh specimens has confirmed the taxonomy of the species and its existence in the area. Some ecological characteristics of the mud lobster, such as size variation, population density, and mound characteristics, are also discussed. The present study also found that construction of massive mounds by mud lobster has posed a conflict to farmers and coastal communities at Buntal area, who regarded the animal as a pest. On the other hand, research on the potential medicinal value of mud lobster in Sarawak is growing. This implies that accurate taxonomy and comprehensive ecological data of *T. anomala* are necessary to support best practices of mud lobster pest management and sustainable harvesting of the animal for medicinal purposes, which eventually lead to conserving the animal.

Keywords: Aautecology, coastal, decapod, mangrove, mud lobster

INTRODUCTION

Mud lobsters are presently described under a single genus *Thalassina* Letreille, 1806 in family Thalassinidae Letreille 1831. The family Thalassinidae is clade in infraorder Gebiidea along with three families, the Axianassidae Schmitt 1924, Laomediidae Borradaile 1903, and Upogebiidae Borradaile 1903 (see De Grave *et al.*, 2009). The current taxonomics study of mud lobsters have listed worldwide a total of 11 valid species; *Thalassina anomala*, *T. australiensis*, *T. emerii*, *T. gracilis*, *T. kelanang*, *T. krempfi*, *T. pratas*, *T. saetichelis*, *T. spinirostris*, *T. spinosa*, *T. squamifera* (Moh & Chong, 2009; Ngoc-Ho & de Saint Laurent, 2009; Sakai & Türkay, 2012; Lin *et al.*, 2016).

Thalassina anomala was first described by Herbst based on a single male specimen (Herbst, 1804; Ngoc-Ho & de Saint Laurent, 2009). Of the 11 known species, *T. anomala* is widely distributed across the Indo-West Pacific region in the west of India to southwest Japan (Ngoc-Ho & de Saint Laurent, 2009). In Malaysia, *T. anomala* has been reported in the peninsular (Selangor, Penang, Negeri Sembilan, Terengganu) and east (Sarawak) (Moh & Chong, 2009; Ngoc-Ho & de Saint

Laurent, 2009; Hassan *et al.*, 2015; Zakaria *et al.*, 2019). The presence of mud lobster in Sarawak has been reported from Kuching and Sri Aman Divisions (Leh, 1982).

The burrowing behaviour of *T. anomala* leads to the construction of massive mounds with extreme architectural and complex functionality (Andriesse *et al.*, 1972; Moh, 2016). However, the construction of massive mounds adversely affects buildings and crop production thus mud lobster is regarded as a pest (Moh, 2016). From the ecological perspective, the burrowing activity of *T. anomala* benefits the overall health of the forest by promoting better soil sedimentology and geochemistry (Andriesse *et al.*, 1972; Havanond, 1987; Ashton & Macintosh, 2002; Dubey *et al.*, 2012; Hossain *et al.*, 2019).

In Sarawak, the presence of mud lobsters had been reported in old literature. Some recent studies have also reported the occurrence of the animal in other areas (Wan Adnan, 2010; Hossain *et al.*, 2019). A medical-oriented research used mud lobster as their research subject, although taxonomic identification to the species level was not conducted (Md Zohir *et al.*, 2018). While the ecological and medical-related study of mud lobsters are paramount, the fundamental aspect of species identity needs to be ascertained beforehand. Therefore, the objective of this study was to determine the species identity of mud lobsters in Sarawak by examining museum collections and fresh specimens.

MATERIALS AND METHODS

Study Site

The checklist of crustaceans of Sarawak Museum showed that the first record of *T. anomala* was from Buntal area but without any information on the location where the specimen was collected (see Leh, 1982). We conducted the ecological study of *T. anomala* at Kg Sg Batu (1°39'55.06"N; 110°21'32.75"E), which is located about 5 km in the southwest of Kg Buntal (1°42'19.34"N; 110°22'05.33"E). The two villages are located within the Buntal area of which Kg Buntal can be was the site of the first record of mud lobster (Figure 1). Therefore, we also searched mud lobsters at Kg Buntal. The ecological study was conducted at a new coconut plot at Kg Sg Batu. The coconut plot is located at high tide mark of which tidal influence of Sg Buntal and Sg Santubong reached the study site during high tide. Three random quadrates were established based on the presence of mounds, and the size of each quadrate was measured at 50.25 m^2, 48.75 m^2 and 26.22 m^2, respectively. The total area of the coconut plot is approximately 1800 m^2 (Figure 5I). The number of mounds at each quadrate were countered and measured for height, diameter, and perimeter of mound area to the nearest 0.1 cm.

Sampling Techniques

We employed five sampling methods (pitfall traps, fishnets, hand-picking, digging, biodegradable insecticide) consecutively (Table 1), and only one (biodegradable insecticide) was successful. A solution of biodegradable insecticide of KENCIS Brand (Cypermethrin 5.5 %) was prepared by diluting 5 millilitres of the insecticides with 7 litres of tap water. A small volume of the solution was sprayed into the mounds to trigger the mud lobster to come out from the burrow. This technique was operated for one day on 17 selected mounds in the three quadrates. The method was effective, where mud lobsters were coming out from the mound after an average 10 minutes of spraying the solution. The mud lobsters were picked by hand and placed in the bucket. At this concentration of 0.07 mg/L, the insecticide residue is expected naturally degraded by microbes in the soil by less than 7 days (see Yin *et al.*, 2013). This suggests the method used in this study might have insignificant effect to environment and biodiversity. Yet, the sampling was not expanded due to the potential threat of damaging the native population of mud lobster and other invertebrates. Before examining and measuring the specimens, the mud lobsters were washed with water to clean the dirt and insecticide residue.

Upon completing the ecological experiment at Kg Sg Batu, a sampling trip was made to new farmland at Kg Buntal and captured a half-dead female of mud lobster at 1.00 o'clock in the afternoon (Figure 5A, B), which was probably attacked by predators or effect of insecticide used by farmers at the area. We have also received specimens of mud lobsters from other farmers of Kg Sg Batu, who also used insecticide to control the mud lobster population. The mud lobster specimens were measured for carapace width (mm), carapace length (mm), total body length (mm) and 4th abdomen length (mm) using a digital caliper. The weight (g) was measured using a digital balance ELB200 Shimadzu brand. The

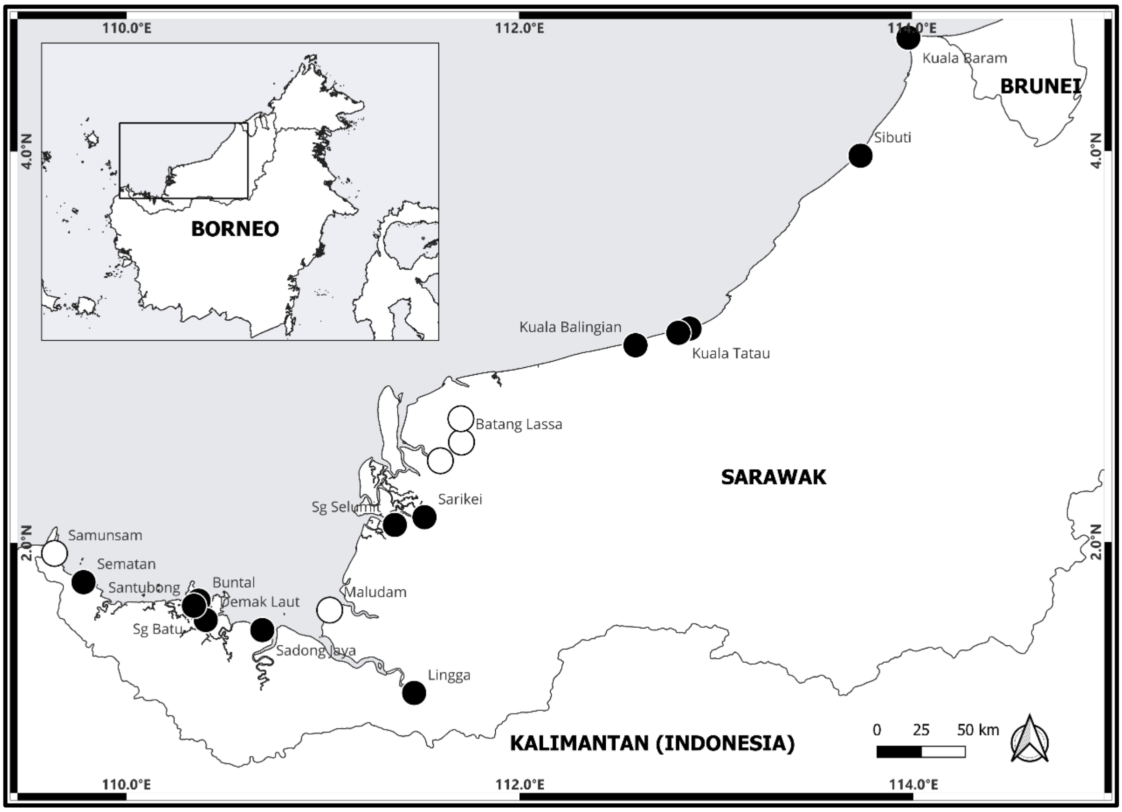

Figure 1. Records of the occurrence of *Thalassina anomala* in Sarawak. Black circles are records with voucher specimens, and white circles are field observations by the second author

specimens were sexed on the basis of the presence of gonopores on inner ventral surface of coxa of 3rd pereopod for female (Figure 3G), and 5th pereopod for male.

Data Analysis

Shapiro-Wilk test was used to check if the data are approximately normal distributed, an assumption required for parametric tests. Similarly, Levene's test was performed to determine if variance of measurements of male and female of mud lobsters are equal, an assumption required for comparing two independent population means. The initial data analysis showed that the data are normally distributed. The Levene's test showed variance of weight and 4th abdominal somite of male and female of mud lobsters are equal thus permit for parametric independent *t*-test. The variance of carapace width, carapace length and total length between male and female of mud lobsters is not equal therefore a Welch's test was used. A logistic regression was run to determine which of the five measurements (i.e., carapace width, carapace length, total body length and 4th abdominal somite) significantly predict sex of the mud lobster. Logistic regress was also used to determine what character of mound (i.e., heigh, opening diameter, perimeter of mound area) that significantly predicting the presence of the mud lobster. All analyses were done at 0.05 of significance level and performed in JASP Package Version 0.14.1 (JASP Team, 2020). Extrapolation method was used to estimate the population and density of *T. anomala* at the coconut plot. The estimation was based on the average of number of individuals and density obtained from the three quadrates with 95 % of confidence intervals.

The growth pattern and condition of *T. anomala* was estimated based on an exponential growth formula of $W = aL^b$. The formula implies the increase of weight (W) of mud lobster is proportionate to the increase of its carapace length (CL). This exponential formula then transformed to $\log W = \log a + b \log L$ to obtain a linear relationship for estimating the intercept, *a* and the slope, *b* of the fitted regression line. The value of *b* indicates the growth pattern, with $b = 3$ is isometric growth, whereas $b < 3$ and $b > 3$ are negative and positive allometric growth, respectively. The condition of mud lobster was estimated using the equation of condition factor, $K = (10000 \times W)/CL^3$, where the value is increasing with well-being of the animal (Grinang *et al.,* 2016).

RESULTS AND DISCUSSION

Historical Records and Geographical Distribution

Records of mud lobster in Sarawak were extracted from journals, unpublished thesis and catalogue of voucher specimens of Sarawak Museum (Man, 1928; Andriesse *et al.,* 1972; Leh, 1982; Ashton *et al.,* 2003; Wan Adnan, 2010; Md Zohir *et al.*, 2018; Hossain *et al.,* 2019; Zakaria *et al.,* 2019). The Sarawak mud lobster is currently represented by a single species, *T. anomala*, that was first recorded from Buntal of southwestern Sarawak in 1891 by John Edgar Anderson Lewis, the first curator (then Pro tem Curator) of Sarawak Museum (Leh, 1982). The other early records were from Lingga and Baram between 1897 and 1928 (see Man, 1928; Leh, 1982). More recent records show the occurrence of *T. anomala* in Sematan, Asajaya, Bintulu, Mukah, Sarikei, and Balingian (Ashton *et al.,* 2003; Wan Adnan, 2010; Md Zohir *et al.*, 2018; Hossain *et al.,* 2019; Zakaria *et al.,* 2019). These records indicated that *T. anomala* is widely distributed in coastal areas and tidal influence habitats in Sarawak, as shown in Figure 1. The massive mounds of mud lobster are prominent in mangrove and nipa forests exclusively at the high tide marks. The records also showed that the distribution of the mud lobster could reach 80 km upstream of Batang Lupar at Sri Aman town.

Description of *Thalassina anomala* from Sarawak

Materials examined in this study: 1 male, CL 70.2 mm, Buntal, 1891, coll. J. E. A. Lewis, specimen in poor condition (Figure 2A–C); 1 male, TL ca. 227.7 mm, on bund Sg Selumit, Rejang, 12 November 1991, coll. Mus. Sar., specimen in poor condition (Figure 2D–I); 4 males, TL 132.0–190.0 mm, 4 females, TL 191.0–235.0 mm (UNIMAS.C.000108), Kg Sg Batu, Buntal area, Santubong, Sarawak, 13 March 2021, coll. A.F. Rusyadi Amnah & J. Grinang; 1 female, TL 169.5 mm (UNIMAS.C.00109), Kg Buntal, Santubong, Sarawak, 14 August 2021, coll. J. Grinang (Figures 2J, 3, 5A, B); 7 males, TL 142.4–227.6 mm, 7 females, TL 187.5–233.0 mm (UNIMAS.C.00110), Kg Sg Batu, Buntal area, Santubong, Sarawak, 4 September 2021, coll. A.A. Abang Sulaiman.

Leh (1982) produced a checklist of crustaceans in the Sarawak Museum Spirit Collection, among other specimens of mud lobster that he identified as *Thalassina anomala* (Herbst, 1804). The specimens of mud lobster were collected from Buntal and Lingga in 1891 and 1897, respectively. No drawing and description were made along with the checklist. Since then, the specimens of the *T. anomala* have never been examined and illustrated. We examined the specimen and other mud lobsters deposited in the Sarawak Museum and provided photographs herewith (Figure 2A–I). A brief description, measurements, and drawings of *T. anomala* are provided by Zakaria *et al.* (2019: figs. 2, 3a, b; table 1), who bought their specimens from markets in Lingga, Sarikei, Balingian, and Tatau. In an experiment on the potential antibacterial of the chemical content of mud lobster, Md Zohir *et al.* (2018: fig. 1) provided a colour image of *T. anomala* without a description. Other studies recorded the presence of *T. anomala* in Sarawak (Andriesse *et al.,* 1972; Ashton *et al.,* 2003; Wan Adnan, 2010), but no illustration or description of the species was provided.

This present study examines 23 fresh specimens of *T. anomala* (11 males, 12 females) caught from the locality where the animal was probably first recorded. The specimens comprised adults and subadults (see Table 2). The key characteristics of all specimens agree very well with the descriptions and illustrations in Herbst (1804: p. 45–49, tab. 62), Sakai (1999: 9, pl. 1C), and Ngoc-Ho & de Saint Laurent (2009: p. 133–134, figs. 2A1, D, D1, 5, 6A, B). The specimens of Buntal area are illustrated herewith and described as having blunt rostrum with distinct tubercles on lateral borders (Figure 3E); a tubercle on the median of 2nd to 5th abdominal sternites (Figure 3D); no spine on cervical groove instead tubercles (Figure 3E); a distinct row of tubercles on the lateral border of palms (Figure 3K). Dimorphism in *T. anomala* is more noticeable in adult specimens, especially the width of abdominal segments, which are broader in females than males (Figure 4). First pereopods in males are unequal, whereas subequal in female specimens (Figure 3I, J, L, M). However, the size variation of the first pereopods in subadult specimens is almost not distinguishable in both sexes. The 2nd to 5th pereopods are similar in size in both sexes across adult and subadult specimens (Figure 3N-Q).

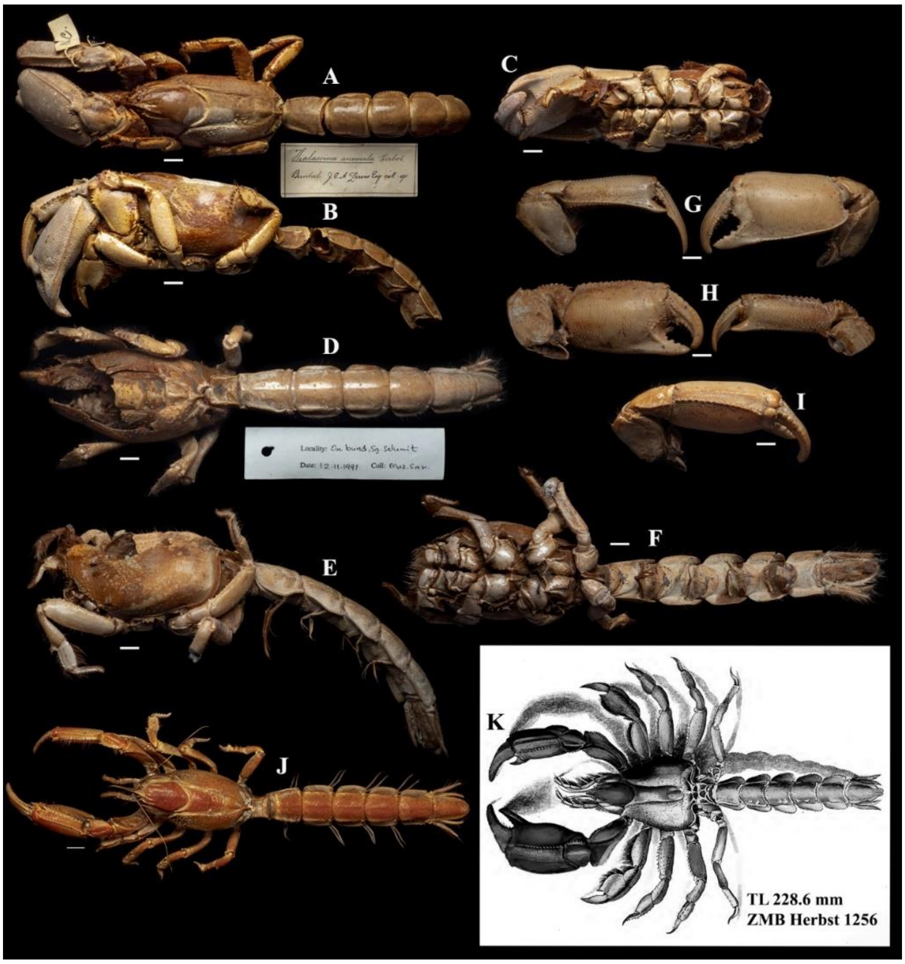

Figure 2. Image of preserved and fresh specimens of *Thalassina anomala* from Sarawak and the drawing of type specimen reproduced from Herbst (1804). A–C, male specimen collected by J.A.E Lewis from Buntal area in 1891; D–I, male specimen collected by Sarawak Museum from Sg Selumit, Rejang in 1991; J, fresh female specimen collected from Kg Buntal area; K, drawing of holotype not in scale. A, D, J, K, ventral view; B, E, lateral left view; C, F, ventral view; G, outer view of chelipeds; H, inner view of chelipeds, I, dorsal view of cheliped. Scale: 10 mm

Table 1. Other sampling methods applied in the ecological experiment

Methods	Procedures
Pitfall traps	• Pitfall traps comprised two sizes of plastic buckets with 30 cm height by 29 cm opening diameter, and 24 cm height by 22 cm opening diameter, respectively. • Holes were drilled to the bottom of the buckets to drain water. • 40 pitfall traps were randomly dug into the soil within the coconut plot (Figure 5I). • This sampling technique was operated for two weeks with 3-day intervals of checking the traps in the morning and evening.
Fishnets	• Fishnets (mesh size 1 inch) were placed around the three quadrates (i.e., 50.25 m^2, 48.75 m^2, and 26.22 m^2). • The nets were checked for every morning or evening for five consecutive days (Figure 5J).
Hand-picking	• Hand-picking technique was performed at night for two consecutive nights considering that the animal is nocturnal.
Digging	• Digging of selected 50 mounds was made by using a spade.

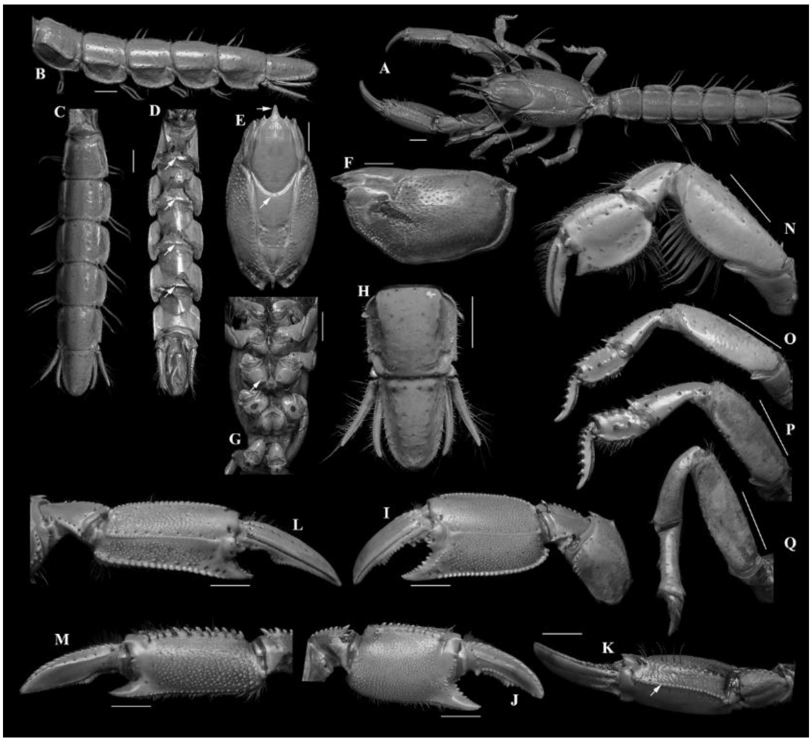

Figure 3. A female *Thalassina anomala* (UNIMAS.C.00109; TL, 165.9 mm) from Kg Buntal, Santubong, Sarawak. A, habitus; B–D, abdomen from lateral, dorsal and ventral views; E, dorsal carapace; F, lateral carapace; G, ventral thorax with arrow shows the gonopore; H, dorsal telson and uropods; I–K, left cheliped at outer, inner and ventral view, respectively; N–Q, outer views of pereiopods, respectively. Arrows show key characteristics. Scale: 10 mm.

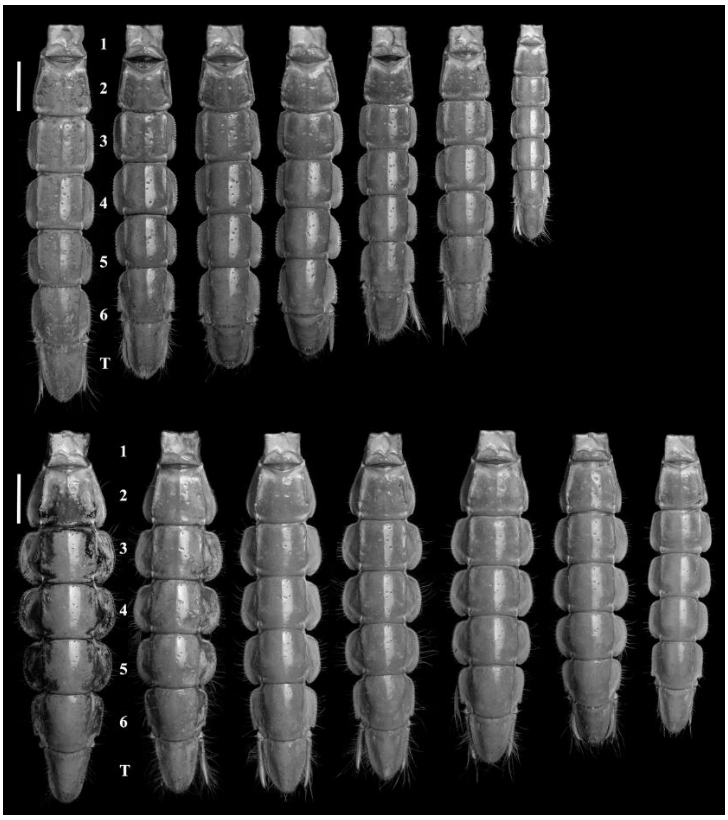

Figure 4. Dorsal view of abdominal somites (1-6, telson) of males (top) and females (bottom) of *Thalassina anomala* (UNIMAS.C.00110) from Kg Sg Batu, Santubong, Sarawak. Scale: 20 mm.

Ecological characteristics

This study was conducted to determine if *T. anomala* shows dimorphism in morphological characters. Sexual dimorphism in size and morphological characters is common in many crustaceans (Alencar *et al.*, 2014; Hidir *et al.*, 2021). We hypothesized that the weight, carapace width, carapace length, total length and 4th abdominal segment of males and females of *T. anomala* are different. Results showed that four characters (i.e., weight, carapace width, carapace length, and 4th abdominal segment) were significantly different between males and females with a p-value less than 0.05 (Table 2). The total length was not significantly different between the sexes (p = 0.055). The female is generally more prominent than the male. However, the result of logistic regression showed that no character significantly predicted the sex of mud lobster (Table 3). Although the width of 4th abdominal segment in females is much broader than the male in all specimens (Figure 5), the logistic regression of the prediction was not significant with p = 0.058. The abdominal segment is broader in female crustaceans could be related with its function to accommodate the egg mass (Sant'Anna *et al.*, 2013). Nonetheless, the p-value of logistic regression for 4th abdominal segment was the least compared to other characters, which implies the abdominal width could be the best character for distinguishing the sex of mud lobster in the wild. The inconsistency of the results could be due to the inclusion of adult and subadult samples in the analysis, and the small sample size, which does not represent the size variation of the entire population of the mud lobster. Zakaria *et al.* (2019) have also demonstrated dimorphism in abdominal width, with the female being significantly broader than the male. They showed that other characters are not significantly different between males and females. The variation of the results between the present study and other analyses may imply a different population of *T. anomala* and the different cohort of the year.

The burrowing behaviour of *T. anomala* and the characteristics of their mounds had been well documented (see Dubey *et al.,* 2012; Kartika & Patria, 2012; Moh, 2016). However, the previous studies did not analyze the measurements of the mound that best predicted the occurrence of the animal inside the burrow. Because mud lobster is very cryptic and continuously constructed their mounds (Kartika & Patria, 2012; Moh, 2016), their presence in each mound is hardly predicted. Kartika & Patria (2012) stated that a new mound is categorized by wet soil outside the mound, whereas Moh (2016) assumed a wet mound is equivalent to a single occupant. However, the sign of occurrence of individual mud lobster in the burrow has never been tested. We explored if there is a measurement that significantly predicted the occurrence of mud lobster inside the burrow by using logistic regression. Our results showed that the height, diameter, and perimeter of the mound area varied very much (Table 4). For example, the diameter of the mound ranges from 10.7 cm to 230.3 cm. The logistic regression showed that none of the measurements significantly predicted the occurrence of the mud lobster inside the burrow (Table 5). It is suggested that future ecological studies shall focus on the sign of the occurrence of individual *T. anomala* inside the burrow. Knowing the sign of the occurrence of individual mud lobster inside the burrow will increase the detection probability which is a crucial parameter in estimating the animal population.

The present study also aims to estimate the abundance and density of *T. anomala* at a new coconut plot. Moh (2016) estimated the density of *T. anomala* based on the active mound per quadrate on the assumption that one active mound is occupied by a single individual. In contrast, we made the estimates directly based on the individual mud lobsters caught from three different sizes of quadrates. Based on the number of individuals per quadrate (3 individuals/m^2), we extrapolated about 38 individuals of *T. anomala* found at an area of 1800 m^2 with a confidence interval of 13 and 68 (Table 6). Similarly, we extrapolated the density of *T. anomala* to about 0.86 individuals per m^2 with a confidence interval of 0.50 and 1.21. Moh (2016) estimated the density of *T. anomala* at Kelanang Shore in Selangor between 0.39 individuals/m^2 and 0.46 individuals/m^2. In Tanjung Jabung Barat, Sumatra, Kartika & Patria (2012) estimated the density of *T. anomala* is between 3.6 and 5.3 nests per 100 m^2. Knowing the detection probability of mud lobster in this study was low, we suggest the reference of these estimates in future studies should be accompanied by the size and condition of the study site and the sampling method used.

The growth pattern and condition of *T. anomala* were estimated from a linear relationship between weight (g) and carapace length (mm). The analysis shows growth pattern of *T. anomala* in the Buntal area is negative allometric, which suggests the increase of body weight is not highly proportionate to the increase of the carapace length, as indicated by $\boldsymbol{b}$ = 2.63 (Table 7)**.** The value of condition of *T. anomala* is low (*K* = 3.07; 95% CI 2.78, 6.88), suggesting a population of poor condition. Zakaria *et al*. (2019) reported an isometric growth pattern for *T. anomala* caught from Sri Aman, Sarikei, Mukah, and Bintulu Divisions as isometric with *b* = 3.02. The variation of growth pattern among different population of crustaceans have been associated with biotic and abiotic factors (Zakaria *et al.,* 2019).

Table 2. Measurement of morphological characters of *Thalassina anomala*, and results of comparison test of size between sex

Measurement	Male		Female		p value	Cohen's d (95% CI)
	Range	Mean ± SD	Range	Mean ± SD		
Weight (g)*	30.00–99.00	65.25 ± 32.57	115.00–181.00	148.75 ± 29.44	0.009 [a]	2.69 (0.61, 4.67)
Carapace width (mm)*	21.10–34.30	28.30 ± 6.34	38.20–43.90	41.45 ± 2.47	0.019 [b]	2.73 (0.38, 4.99)
Carapace length (mm)**	45.50–81.50	67.14 ± 12.72	66.50–82.90	77.18 ± 4.89	0.030 [b]	1.04 (0.10, 1.95)
Total length (mm)**	132.00–231.70	189.28 ± 36.36	187.50–235.00	214.52 ± 16.58	0.055 [b]	0.89 (-0.12, 1.77)
4th Abdomen (mm)***	15.70–27.90	24.73 ± 4.298	25.30–37.90	32.21 ± 3.87	0.005 [a]	1.83 (0.53, 3.08)

Note: [a]Student's *t*-test, [b]Welch's test; sample size: *4 individuals each sex, **11 individuals each sex, ***7 individuals each sex.

Table 3. Results of logistic regression of predicting sex of *Thalassina anomala* from the morphological characters

Coefficients	Estimate	Odd Ratio	Wald's Test	p-value
Weight (g), n = 8	-2.811	0.060	4.714×10^{-7}	0.999
Carapace width (mm), n = 8	-11.860	7.070×10^{-6}	2.776×10^{-7}	1.000
Carapace length (mm), n = 22	-0.140	0.870	3.433	0.064
Total length (mm), n = 22	-0.036	0.964	3.106	0.078
4th abdomen width (mm), n = 14	-0.692	0.501	3.504	0.058

Table 4. Measurement of 17 mounds of *Thalassina anomala* from three quadrates (=125.22 m^2) at Kg Sg Batu

Parameters	Range	Mean ± SD
Mound Height (cm)	22.40–49.50	30.27 ± 7.41
Mound Diameter (cm)	10.70–230.30	62.53 ± 57.02
Perimeter of Mound Area (cm)	96.40–314.20	166.73 ± 79.40

Table 5: Results of logistic regression of predicting the occurrence of *Thalassina anomala* from the characteristics of mounds. n = 14

Coefficients	Estimate	Odd Ratio	Wald's Test	p-value
Mound height (cm)	-0.024	0.977	0.099	0.754
Mound diameter (cm)	-0.005	0.995	0.215	0.643
Perimeter of mound area (cm)	0.005	1.005	0.385	0.535

Table 6. Extrapolation of the number of individuals and density of *Thalassina anomala* for the total study area (=1800m^2)

Parameters	No. of individuals	Density (individual/m^2)
Quadrate 1 (50.25 m^2)	3	0.060
Quadrate 2 (48.75 m^2)	4	0.082
Quadrate 3 (26.22 m^2)	1	0.038
Mean in 3 quadrates (125.22 m^2) (95% CI)	3 (1, 4)	0.06 (0.04, 0.08)
Extrapolation to total area (1800 m^2) (95% CI)	38 (13, 68)	0.86 (0.50, 1.21)

Note: Non-significant linear regression between quadrate size and number of individuals (r = 0.894, p = 0.296), and density, r = 0.727, p = 0.482).

Table 7. Results of carapace length-weight relationship, and condition factor of *Thalassina anomala* based on total 8 fresh specimens

Weight (g)	Carapace length (mm)	***a*** (95% CI)	***b*** (95% CI)	*K* (95% CI)
107.00±53.09	68.75±14.58	-2.84 (-3.91, -1.77)	2.63 (2.05, 3.22)	3.08 (2.78, 6.88)

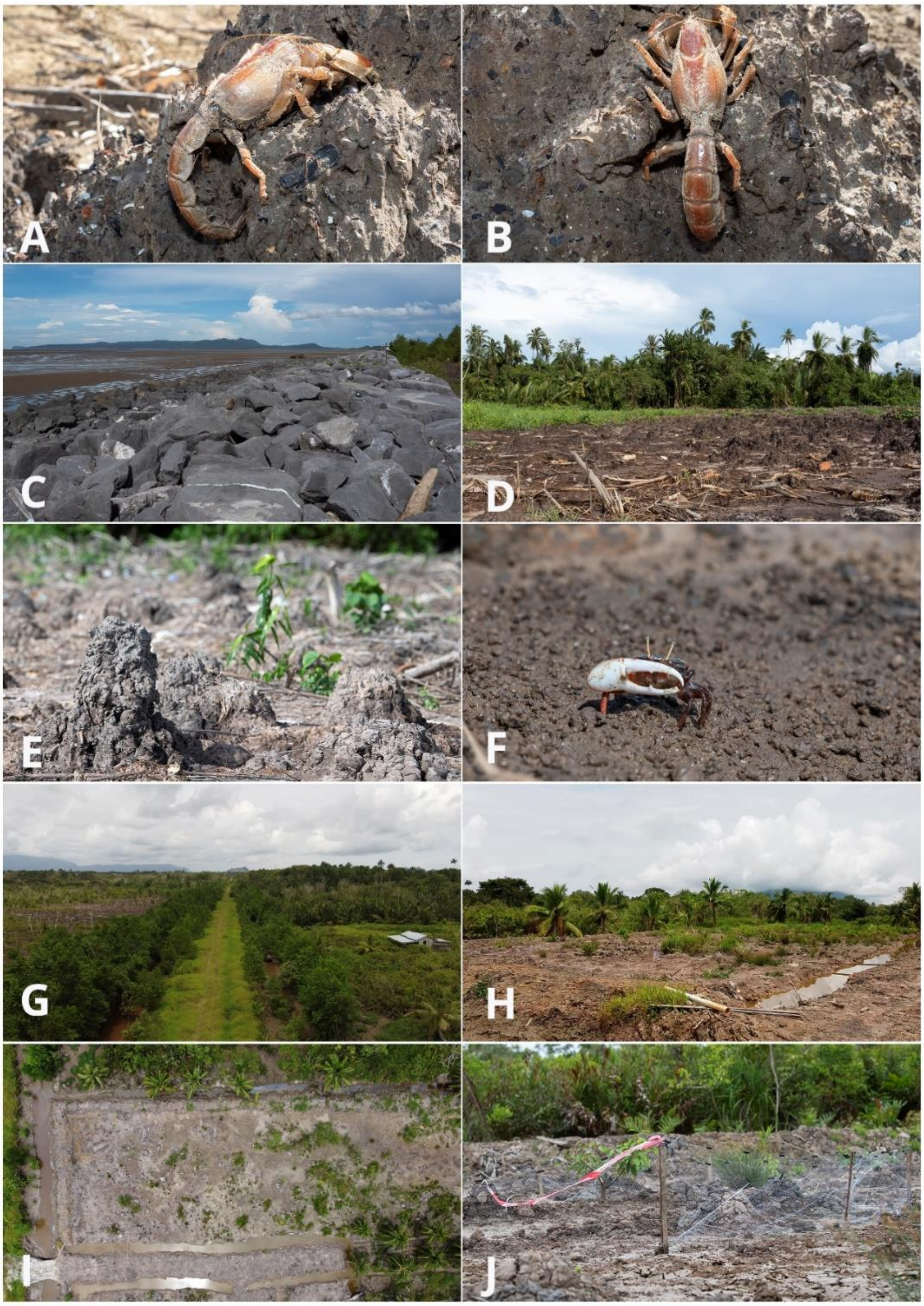

Figure 5. A-F, observation at Kg Buntal, Santubong; A, B, a female *Thalassina anomala* on its mound; C, rock wall to prevent coastal erosion; D, distribution of mounds on the inland side of the rock wall; E, a fresh mound ca. 42 cm height; F, a male *Tubuca dussumieri*, co-existed with mub lobster; G-J, observation at Kg Sg Batu, Santubong; G, aerial view of agriculture plots with patches of secondary vegetation; H, habitat of mud lobster is recently converted to coconut plot; I, aerial view of sampling plot, 30 m × 60 m; J, netting around the mounds is one of methods employed in the study

Field observation found that *T. anomala* is co-exists with several sesarmid crabs, including *Tubuca dussunieri* (Figure 5F), *Parasesarma eumolpe*, *P. indiarum*, and mudskipper, *Periophthalmodon schlosseri.* Anecdotal accounts with the farmers indicate that mud lobster caused damages to crops and buildings, and insecticides are used to control the burrowing activity by the animal. The activity of *T. anomala* is controlled by spraying insecticide around the perimeter of crops and buildings. This technique has only prevented the mud lobster from causing more damage, but it is not able to control the entire population. The use of insecticides might have affected the population of *T. anomala*, and the syntopic species. Moh (2016) demonstrated that planting the combination of two species of grasses, *Chrysopogon zizanioides* and *Cyanodon dactylon* has effectively reduced the infestation of mud lobsters.

CONCLUSION

The presence of *Thalassina anomala* in coastal areas of Sarawak is now documented. It is distributed across coastal areas mainly associated with tidal influence habitats in mangrove and nipa forests. The burrowing behaviour of mud lobster has caused damage to agricultural crops and buildings therefore, it is regarded as a pest by farmers and villagers. The application of insecticide in controlling the mud lobsters will potentially affect the population of the animal and non-target species. On the other hand, few studies show chemical contents of mud lobster meat have potential medicinal value. All these imply that accurate taxonomy and comprehensive ecological data of *T. anomala* are necessary to support best practices of mud lobster pest management and sustainable harvesting of the animal for medicinal purposes, which eventually lead to conserving the animal.

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