Searching for Nature Stories 2019

Cheung Chuk Shan College – Group R09

Chow Hau Yung (S5)

Sze Nok Lam (S5)

Wong Hiu Yee (S5)

Wong Yin Ka (S5)

Yu Chun Wai (S5)

Architect in Milky Attire – hood-building behaviour of *Austruca lactea*

CONTENT

ABSTRACT

Austruca lactea is a species of fiddler crab and its male crabs are commonly known to dig burrow for defence and reproduction. It was observed that some of them also build earthen structure known as hoods above the entrance of their burrows. Such hoods are not observed for every burrow. As the function of hoods should be related to the burrow, it is hypothesised that the main purpose of building hoods in addition to burrows is for mating.

Our investigation aimed at finding the relationship between hoods building habits of *A. lactea* and the reasons behind such behaviour. Firstly, to investigate about the sex ratio, it was shown that there was a significant rise in female ratio from June to August, even though its amount remained lower than that of male throughout all the field studies. Secondly, by comparing the hood density from May to August. The density increased from April to May and remained high during the summer. It declined a little towards the late August. It indicated the hood building is highly related to reproductive cycle of *A. lactea*. Thirdly, as the size of hoods increased with the carapace of the *A. lactea*, a larger hood could symbolize the competitive edge of the crabs. To further investigate whether mating propelled *A. lactea,* experiment was conducted to find out the effects on hoods building with the presence and absence of female crabs. Nevertheless, no hood was found in both experimental and control set-ups. In addition, hood may be built for territory defence against wandering males. However, there was also no clear relationship between hood to burrow ratio and crabs density found. As a result, the hood building behaviour of *A. lactea* had no clear relationship with reproduction and territory defence.

Despite the fact that no solid conclusion could be drawn for the reasons of hood building, it is confirmed that the changes of hood density vary over summer. The reason behind such phenomenon is remained unknown.

INTRODUCTION

Introduction to the research topic

It is common that crabs living in mangrove make burrows for shelter. Some of them also construct an arched, earthen structure at the entrance of their burrows, known as hood. *Austruca lactea*, a species of fiddler crabs that are mainly found under mangrove trees and in muddy areas beside rivers, has this habit. Both normal burrows without arched structure and hoods can be found in their habitat. In our study, we hope to investigate the reasons behind this special hood-building behaviour.

Objectives

1. To investigate the sex ratio of *A. lactea* in the field site
2. To investigate the change of hood density in the field site from May to August
3. To study the relationship between hood size and the size of male *A. lactea*
4. To investigate the reasons for the hood-building behaviour of *A. lactea*

Research questions

1. What is the sex ratio of *A. lactea* in the field site?
2. What is the hood-burrow ratio of *A. lactea* in the field site?
3. Is there any trend of the hood density in the field site from May to August?
4. Is there any relationship between the size of male *A. lactea* and the size of its hood?
5. Why does *A. lactea* build hoods instead of normal burrows?

Background information of *A. lactea*

Classification:

Kingdom	Animalia
Phylum	Arthropoda
Class	Malacostraca
Order	Decapoda
Family	Ocypodidae
Genus	Austruca
Species	*A. lactea*

The colour of *A. lactea* mainly ranges from white to milky. They have a broad inter-orbital region and the ratio of the frontal width to fronto-orbital width is 1:4 to 1:3. The large white clasping claw, coupled with a dark small claw and eight legs are the unique features that could only be found in males, while a female one has two white small claws and eight legs.

For the habitats, *A. lactea* can be found in large numbers in soft silty to muddy substrates of sea beaches, brackish inter-tidal mudflats, lagoons, backswamps, mangroves, salt marshes, estuaries and creek banks.

For the food sources, as detritus feeders, the microheterotrophs (bacteria and protozoa) or meiofauna (nematodes) that exist on the surface of sand or mud particles are their source of food.

Reproduction of *A. lactea* is restricted to spring and early summer, while recruitment occurs at the end of summer. That is the period for our investigation on their hood building habits.

Males of *A. lactea* sometimes construct sand structures, known as hoods, at the entrance to their burrows. A hood is an arched, earthen structure at the entrance of the burrows. After the habitat is exposed for 0.5 to 2 hours, some males start building hoods.

Figure 1. – A male *A. lactea*[1]

Figure 2. – A female *A. lactea*

Figure 3 – *A. lactea* tries to build a hood on its own

[1] Uca Lactea, Environment Education, https://activity.dbnsa.gov.tw/ee/Article.aspx?Lang=2&Arti=05004200

METHODOLOGY

3.1. Summary of field study

Date (YYYY-MM-DD)	Time (Temperature)	Venue	Event
2019-04-18	11:00 – 16:00 (22.5˚C)	Tai Tam	• Collection of data on the number of male and female *A. lactea,* burrows and hoods • Measurement of male *A. lactea* size and their respective hood size • Observation of the hood-building behaviour
2019-05-19	13:30 – 17:00 (30.5˚C)		
2019-07-29	13:00 – 17:00 (32˚C)		• Collection of data on the number of male and female *A. lactea,* holes and hoods • Measurement of male *A. lactea* size and their respective hood size
2019-08-26	10:30 – 12:30 (25.5˚C)		• Setting up of iron cages
2019-08-28	13:00 – 15:00 (35.5˚C)		• Collection of data on the number of holes and hoods inside iron cages • Collection of data on the number of male and female *A. lactea,* holes and hoods outside of the cages
2019-09-13	14:30 – 16:30 (25.5˚C)		• Collection of data on the number of *A. lactea*, holes and hoods inside iron cages • Removal of iron cages

3.2. Description of field site

A mudflat site near Tai Tam Reservoir was chosen due to the abundance of *A. lactea* in the site and its accessibility. This field site has the area of approximately 750 m^2, which is separated into 2 parts by a delivery pipe.

Figure 4. – Satellite image of field site

Figure 5. – Map of field site

Figure 6. – Overview of field site

3.3. Objective 1 – To study the sex ratio of *A. lactea*

The sex ratio refers to the ratio of males to females in a population. In most sexually reproducing species, the ratio tends to be 1:1. For various reasons, especially in mating season, many species deviate from an even sex ratio, either periodically or permanently. It is believed that the increasing female to male ratio indicates the increasing activity of female. Hence, the higher female to male ratio in the period, indicating that that period is more likely to be a mating season.

Field studies were carried out to find out the sex ratio of *A. lactea* inside the field site, with 3hree random spots were selected preferably for the counting as replicates in each field study.

As fiddler crabs are very sensitive to the environment, a little vibration of the ground caused by human movement would make them immediately return to the burrows or hoods in the mudflat. As a result, direct counting of the fiddler crabs beside them is not possible. Thus, binoculars were used to observe the environment inside the quadrat and avoid disturbing the crabs with steady position.

In the field studies, it was assumed that *A. lactea* were evenly distributed over the surface of the mudflat. Furthermore, it was assumed that the burrows and hoods seen inside the quadrats were all built by the *A. lactea* inside, while precautions had been taken by excluding the burrows and hoods built by other species of fiddler crabs that could be observed living inside it during counting.

Procedure

1. A 1m × 1m quadrat was placed randomly on the mudflat.
2. Three people stood a meter away from the quadrat, evenly spread around it so that the quadrat could be viewed from different angles to increase the accuracy.
3. The number of male and female *A. lactea* inside the quadrat was counted with the aid of binoculars
4. Step 3 was repeated for 2 more times at 10-minute intervals.
5. Step 1 to 4 were repeated for two more times to increase the reliability of the results.

3.4. Objective 2 – To study the change of hood density from April to August and the relationship between hood to burrow ratio and crab density

Hood building is one of the major activities of *A. lactea* and most of the other species of fiddler crabs. A significant change in the density of hoods built by *A. lactea* can reflect the change in frequency of their activities within a period, including the possibility of reproduction.

Besides, there is a possibility that the hoods are used for defence against competitors in addition to attracting females. With higher crab density, there are more cut-throat competitions on natural resources such as food and the need for defence increases.

According to scientific literature[2], the reproductive season of *A. lactea* was between June to August. Since our investigation lasted from early June to early September, the hood density from early summer to late summer can be compared to verify the hypothesis of whether mating is the reason for the hood-building behaviour of *A. lactea*. As we hypothesized that the

[2] Hood Building and Territory Usage in the Fiddler Crab, *Uca lactea* (De Haan, 1835), Retrieved 18 August 2005, https://www.jstor.org/stable/20107584

purpose of this behaviour is related to reproduction. The hood may serve as an attraction to the female and enhance the chance of mating. An increase of hood density inside a habitat during its reproductive season may possibly be an evidence that supports the hypothesis.

On the other hand, if the hoods are used for territory defence, the hood to burrow (H:B) ratio should increase with an increase in crab density. The preference of crabs in choosing to build hoods or simply burrows under difference extent of competition can be studied.

Procedure

1. A 1m × 1m quadrat was placed randomly on the mudflat.
2. The number of hoods and burrows was counted
3. Step 1 to 2 were repeated for two more times
4. The data of hood densities collected in May, July and August were plotted on a scatter diagram against time to investigate the trend of hood density.

3.4. Objective 3 – To study the relationship between hood size and size of male

Scientific research already suggested that the claws of males of different species of fiddler crabs are sexual characteristics that can allow the males to attract females[3]. According to James Gorman[4], a male with larger body size implies that he has been living for longer time, thus implying that he is more likely to survive in the habitat for a longer time. His ability to survive may imply that some genes favourable for survival may be present in this male. Females may consider it as a smart choice to mate with this male. Thus, with larger claws, male fiddler crabs are more capable of manoeuvring. Yet, as some research suggested that the hoods built by *A. lactea* facilitate reproduction without strong scientific proof, we would like to study the presence of relationship between hood size and size of male A. *lactea* so as to prove that hood building could facilitate reproduction.

Male *A. lactea* with larger claws are more likely to provide female a larger and tougher shelter. As females have to incubate their egg sponges for two weeks before returning to the surface, it is important for them to stay in a large and safe burrow in the meantime. The hood might be used to give the females an impression that it is safe.

In this experiment, we used the size of carapace of the fiddler crab as a parameter and assumed that the size of carapace is proportional to the size of the claw of an individual *A. lactea*. We measured sizes of different male *A. lactea* and compared them with the size of their corresponding hoods. We aimed at investigating the hood-related features of *A. lactea*. Hence, only those hoods with *A. lactea* living inside would be taken into account.

Procedure

1. The width, length and the height of the hood were measured by Vernier calipers.

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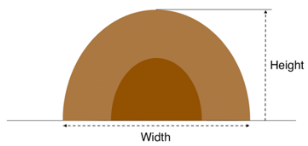
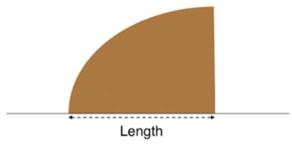
[3] Evolutionary variation in the mechanics of fiddler crab claws, Retrieved 15 July 2019 https://bmcevolbiol.biomedcentral.com/articles/10.1186/1471-2148-13-137

[4] For Fiddler Crabs, 'Size Does Matter'. Retrieved September 8, 2019, from The New York Times. https://www.nytimes.com/2018/02/26/science/fiddler-crabs-claws.html

	Figure 7. – Front view of the hood		Figure 8. – Side view of the hood

2. The fiddler crab living inside the hood was captured.
3. The width of carapace of the fiddler crab was measured by Vernier caliper.

3.6. Objective 4 – To investigate the reasons for building hood

Some of the research suggested that the hood-building behaviour of *A. lactea* is to facilitate its reproduction[5]. Yet, there is not any strong proof or evidence for this claim. Hence we would like to test whether this claim is true by experimental method.

Two groups of crabs were separated into two different cages with the same environments to ensure that the presence of females was the only independent variable. If hoods are found in the set-up with both male and female crabs but not in the one without females, it shows that the males do not see a need in building hoods in an all-male environment. Thus, this can prove that the purpose of hood building is to attract females. To ensure the hood building behaviour is only due to the presence of existing of females, It was assumed that *A. lactea* could not escape the cages and no other crabs could enter the cages. In order for the iron cages to resemble the natural environment, the cages were put in the field site where the crabs were captured. The soil inside the cages was digged from the same area of the location of the cages.

Material

- 2 cages made up of wire netting (pore size: 6mm) with the size of 50cm (length) × 50cm (width) × 35cm (height)

Procedure

1. The 2 cages were filled with mud collected from the field site with a depth of 15 cm.
2. 5 male and 5 female *A. lactea* were placed inside the cage of experimental set-up.
3. Step 2 was repeated with 10 male *A. lactea* for another cage of control set-up.
4. The set-ups were left on land surface alone for 2 weeks.
5. The number of hoods built inside the cage was counted.
6. All soil was dug out and the number of crabs inside were counted.

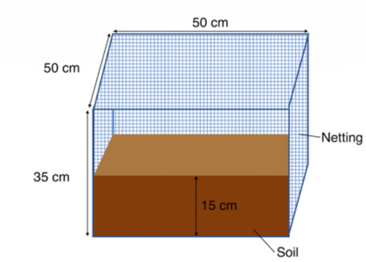


Figure 12. – Annotated diagram of the set-up	**Figure 13. – Sealed experimental set-up**	**Figure 14. – Unsealed experimental set-up**

[5] A mechanism for visual orientation may facilitate courtship in a fiddler crab Tae WonKimabJohn H.Christyc https://www.sciencedirect.com/science/article/pii/S0003347214004606?via%3Dihub

RESULTS

4.1. Results of Objective 1 – To study the sex ratio of *A. lactea*

Table 1 : Table showing the number of *A. lactea* on four day of field study

Date (YYYY-MM-DD)	Replicate	Time instant 1												Time instant 2								Time instant 3										Average	
		Number of males						Number of females						Number of males				Number of females				Number of males					Number of females					Number of males	Number of females
		Cross checking					Average	Cross checking					Average	Cross checking			Average	Cross checking			Average	Cross checking				Average	Cross checking				Average		
		1	2	3	4	5		1	2	3	4	5		1	2	3		1	2	3		1	2	3	4		1	2	3	4			
2019-04-18	1	21	21	24	/	/	22.00	1	1	3	/	/	1.67	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	22.00	1.67
	2	9	8	10	8	8	8.60	0	0	0	1	0	0.20	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	8.60	0.20
	3	5	8	8	8	/	7.25	1	1	1	1	/	1.00	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	7.25	1.00
2019-05-19	1	12	10	11	/	/	11.00	4	4	3	/	/	3.67	13	15	11	13.00	3	3	2	2.67	15	15	13	/	14.33	3	3	2	/	2.67	12.78	3.00
	2	30	31	/	/	/	30.50	1	2	/	/	/	1.50	25	27	/	26.00	4	5	/	4.50	28	30	/	/	29.00	3	1	/	/	2.00	28.50	2.67
	3	9	8	/	/	/	8.50	3	4	/	/	/	3.50	9	11	/	10.00	3	4	/	3.50	10	9	11	9	9.75	4	3	4	5	4.00	9.42	3.67
2019-07-29	1	10	8	8	/	/	8.67	3	3	2	/	/	2.67	7	10	8	8.33	4	3	3	3.33	9	8	5	/	7.33	3	3	4	/	3.33	8.11	3.11
	2	9	10	10	/	/	9.67	2	2	2	/	/	2.00	9	9	8	8.67	2	1	2	1.67	10	9	8	/	9.00	1	2	2	/	1.67	9.11	1.78
	3	8	12	14	/	/	11.33	1	0	0	/	/	0.33	10	10	10	10.00	1	3	0	1.33	12	11	10	/	11.00	2	3	3	/	2.67	10.78	1.44
2019-08-28	1	7	6	7	/	/	6.67	4	2	2	/	/	2.67	5	7	6	6.00	2	4	2	2.67	9	6	7	/	7.33	4	2	2	/	2.67	6.67	2.67
	2	7	6	7	/	/	6.67	2	1	2	/	/	1.67	9	10	9	9.33	2	1	0	1.00	10	9	8	/	9.00	1	2	2	/	1.67	8.33	1.44

P.S. All data are corrected to 2 d.p.

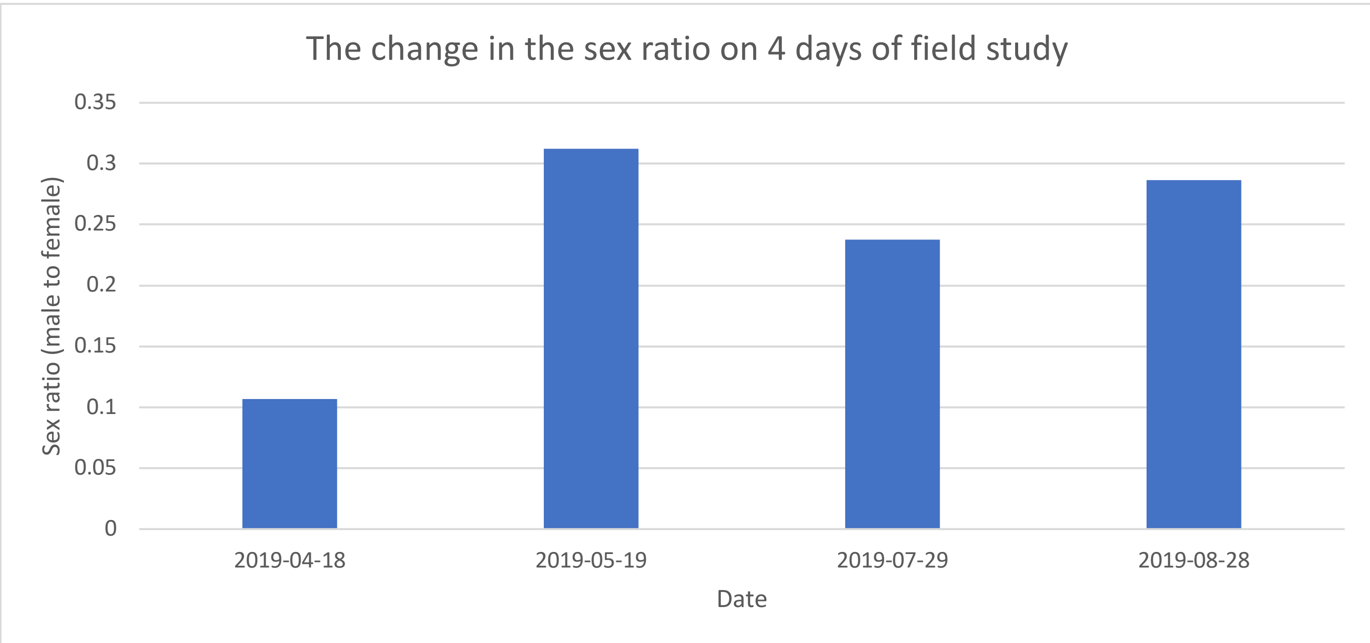
Table 2 : Table showing the sex ratio of *A. lactea* on four days of field study

Date (YYYY-MM-DD)	Replicate	Average number of male crabs	Average number of female crabs	Proportion of male to female	Average proportion of male to female
2019-04-18	1	22.00	1.67	0.08	0.11
	2	8.60	0.20	0.02	
	3	7.25	1.00	0.14	
2019-05-19	1	12.78	3.00	0.23	0.31
	2	28.50	2.67	0.09	
	3	9.42	3.67	0.39	
2019-07-29	1	8.11	3.11	0.38	0.24
	2	9.11	1.78	0.20	
	3	10.78	1.44	0.13	
2019-08-28	1	6.67	2.67	0.40	0.29
	2	8.33	1.44	0.17	

P.S. The shaded data are discarded as it deviated from the majority a lot.

P.S. All data are corrected to 2 d.p.

Graph 1. The change in the sex ratio on 4 days of field study



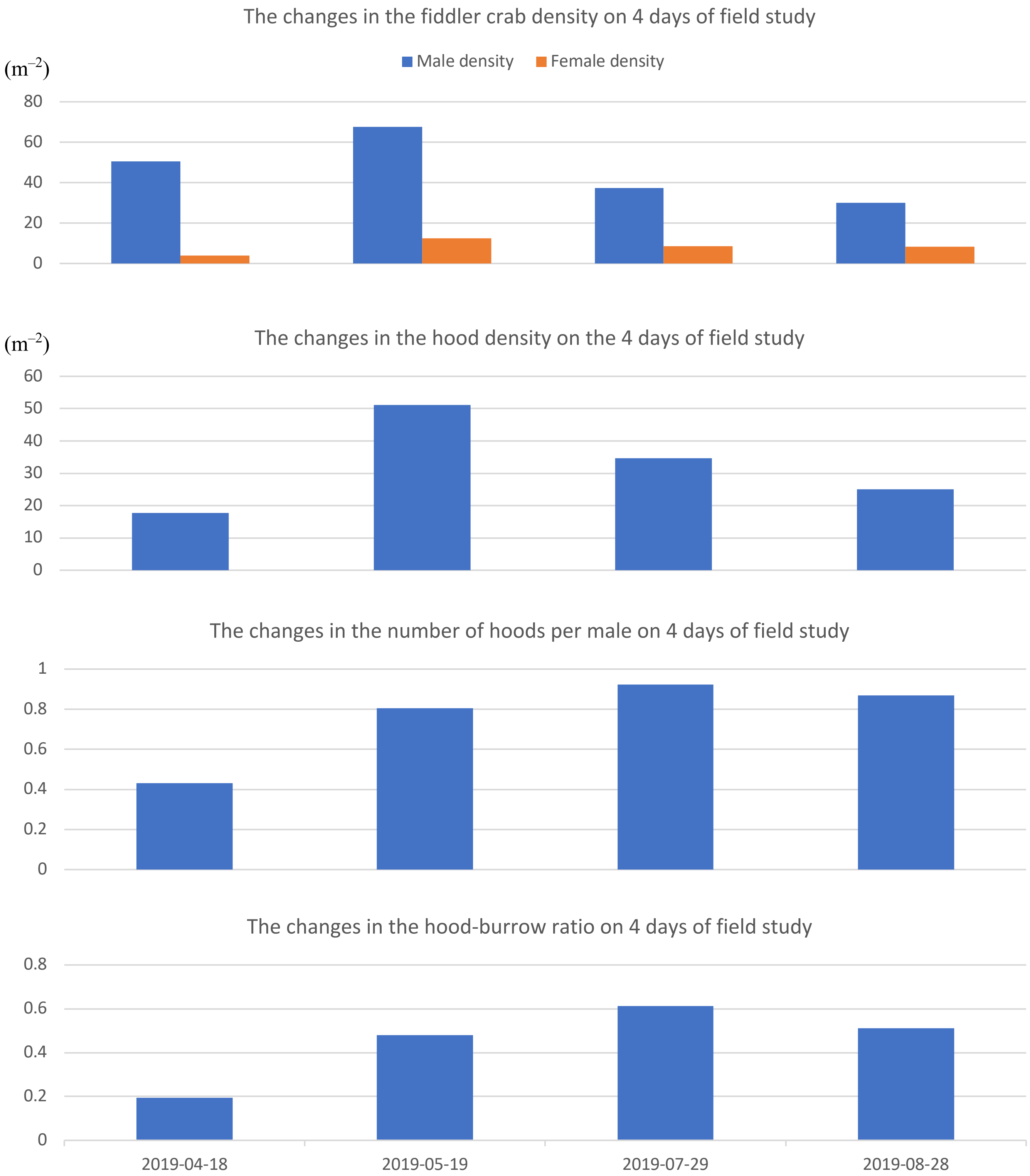
4.2. Results of Objective 2 – To study the change of hood density from April to August and the relationship between hood to burrow ratio and crabs density

Table 2. Table showing the hood to burrow ratio, hood density and number of hoods per male on 4 days of field study

Date (YYYY-MM-DD)	Replicate	Number of hoods						Number of burrows						Hood-burrow ratio	Hood density (m^{-2})	Hoods per male	Average hood-burrow ratio	Average hood density (m^{-2})	Average hoods per male
		Cross checking					Average	Cross checking					Average						
		1	2	3	4	5		1	2	3	4	5							
2019-04-18	1	5	5	5	5	/	5.00	30	35	35	23	/	34.00	0.15	20.00	0.23	0.20	17.78	0.43
	2	4	3	4	4	4	4.00	18	19	20	18	16	19.50	0.21	16.00	0.47			
	3	5	4	2	4	/	4.33	18	18	13	21	/	19.00	0.23	17.33	0.60			
2019-05-19	1	12	13	/	/	/	12.50	21	21	/	/	/	21.00	0.60	50.00	0.98	0.48	51.11	0.81
	2	17	18	20	/	/	18.33	44	38	38	/	/	40.00	0.46	73.33	0.64			
	3	8	10	5	/	/	7.50	21	23	16	/	/	19.50	0.38	30.00	0.80			
2019-07-29	1	8	8	8	/	/	8.00	10	11	12	/	/	11.00	0.73	32.00	0.99	0.62	34.67	0.92
	2	7	6	7	/	/	6.50	13	11	12	/	/	11.50	0.57	26.00	0.71			
	3	10	10	13	/	/	11.50	21	22	20	/	/	21.00	0.55	46.00	1.07			
2019-08-28	1	9	9	6	/	/	8.00	17	17	18	/	/	17.33	0.46	32.00	1.20	0.51	25.00	0.87
	2	4	3	6	/	/	4.50	9	9	7	/	/	8.00	0.56	18.00	0.54			

Table 3. Table showing the fiddler crab density on the 4 days of field study

Date (YYYY-MM-DD)	Replicate	Average number of male crabs	Average number of female crabs	Male crab density (m^{-2})	Female crab density (m^{-2})	Average of male crab density (m^{-2})	Average of female crab density (m^{-2})
2019-04-18	1	34.00	6.80	20.00	0.23	5.35	0.43
	2	19.50	4.88	16.00	0.47		
	3	19.00	4.38	17.33	0.60		
2019-05-19	1	21.00	1.68	50.00	0.98	2.15	0.81
	2	40.00	2.18	73.33	0.64		
	3	19.50	2.60	30.00	0.80		
2019-07-29	1	11.00	1.38	32.00	0.99	1.66	0.92
	2	11.50	1.77	26.00	0.71		
	3	21.00	1.83	46.00	1.07		
2019-08-28	1	17.33	2.17	32.00	1.20	1.97	0.87
	2	8.00	1.78	18.00	0.54		



From top to bottom :

Graph 4. The change in the fiddler crab density on 4 days of field study

Graph 5. The change in the hood density on the 4 days of field study

Graph 6. The change in the number of hoods per male on 4 days of field study

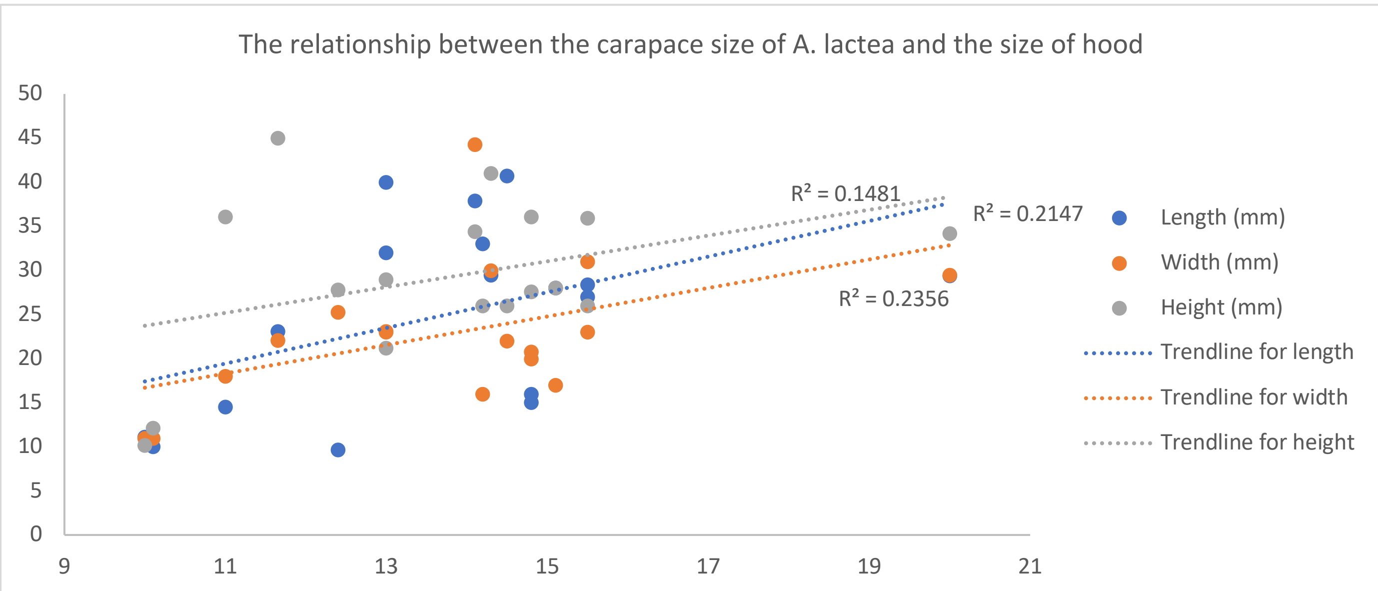
Graph 7. The change in the hood-burrow ratio on the 4 days of field study

4.3. Results of Objective 3 – To study the relationship between hood size and size of male *A. lactea*

Table 4. Table showing the width of carapace of A. lactea and the length, width, height of hoods that they built

Date (YYYY-MM-DD)	Replicates	Size of hood			Width of carapace (mm)
		Length (mm)	Width (mm)	Height (mm)	
2019-04-18	1	15	20.8	36.1	14.8
	2	9.65	25.3	27.8	12.4
	3	16	20	27.6	14.8
	4	23.1	22.1	45	11.65
	5	14.5	18	36.1	11
	6	/	/	/	/
2019-05-19	1	29.4	29.5	34.2	20
	2	37.9	44.3	34.4	14.1
	3	32	23	29	13
	4	40	23.1	21.2	13
	5	40.7	22	26	14.5
	6	28.4	23	26	15.5
2019-07-29	1	11.1	11	10.2	10
	2	10	11	12.1	10.1
	3	28	17	28	15.1
	4	29.45	30	41	14.3
	5	33	16	26	14.2
	6	27	31	35.95	15.5

Graph 8: The relationship between the carapace size of *A. lactea* and the size of the hood



4.4. Results of Objective 4 – To investigate the reasons for building hood

Table 5. Table showing the number of crabs inside the 2 set-ups after 2 weeks

Numbers		Experimental set-up	Control set-up
Number of males	Initial	5	9
	After two weeks	4	6 (and 2 abscised claws)
Number of females	Initial	4	0
	After two weeks	3	0
Number of burrows	Initial	0	0
	After two weeks	7	6
Number of hoods	Initial	0	0
	After two weeks	0	0

			
Figure 17. – Burrows found in the experimental set-up	Figure 18. – Burrows found in the control set-up	Figure 19. – Ground after removal of experimental set-up	Figure 20. – Ground after removal of control set-up

4.5. Extra findings in the experimental set-up

		Figure 21 – 22. – Dark grey soil found under the topmost layer

In the experimental set-up, after 2 weeks, when the topmost layer of soil was removed, soil of a dark grey colour was found beneath. However, there was no dark grey soil present in the control set-up. In the field site outside the cages, soil of dark grey colour was also present beneath the topsoil layer at approximately 10 to 15 cm depth, and was in a water-logged state with water exuded. Yet, the dark grey soil in the control set-up did not show a similar state of being water-logged.

On the other hand, the soil in the experimental set-up was more compact than that in the control set-up. It was easier to dig the soil in the control set-up than it was in the experimental set-up. A shovel had to be used to dig the soil in the experimental set-up, while digging soil by bare hands was possible in the control set-up.

DISCUSSION

5.1. Discussion on Objective 1 – To study the sex ratio of *A. lactea* in the field site

According to table 1, the sex ratio of the fiddler crabs varies with time in a generally increasing trend. The male to female ratio increased from April, when the maximum ratio was below 1:0.15, to May, when the maximum ratio increased to around 1:0.4. The maximum male to female ratio was relatively stable after May, maintaining at around 1:0.4. The gradual increase in the ratio shows that more female fiddler crabs wandered around on the surface, implying that they became more active from May to August, thus proving the fact that the reproductive season of *A. lactea* is between June to August.

Also, the value of male to female ratio(M:F ratio) is always below 1:1, showing that the community of *A. lactea* is in a state of gender imbalance with extremely low population of females. This is an abnormal data as naturally the M:F ratio should be near to 1:1. The possible reason for this may be due to the smaller size of female. It is difficult to spot female crabs easily. Secondly, the female crabs may leave their burrow later than male. The counting process of male and female crabs normally finished within the first hour of low tide. Female may come out for food in the later period of the time.

Yet, on 28th August, an extremely high temperature, 35.5˚C, was recorded. Such high temperatures may cause the crabs to hide inside the burrows so as to prevent dehydration due to strong insolation, explaining the sudden decrease in number of crabs after July. As a result, fewer *A. lactea* were active, and hence the number of crabs counted on 28 August could only show the decreased activity and is expected to be an underestimation.

Also, two replicates in Table 2 (Replicate 2 in 2019-04-18 and Replicate 2 in 2019-05-19) were discarded due to the unusual value which is considerably smaller than the other replicates obtained in the same day. Assuming *A. lactea* were evenly distributed around the field site, we conducted random sampling. Nonetheless, the actual situation may not be true that the distribution of *A. lactea* was not consistent, resulting in an abnormally small value in the replicates. It showed clear that the distribution of *A. lactea* is not even. Some areas may have a larger population of crabs. The soil texture, availability of food and water may lead to such uneven population in the field.

5.2. Discussion on Objective 2 – To study the change of hood density from April to August and the relationship between hood to burrow ratio and crabs density

Replicates were made in different parts of the site. Since the locations for the replicates were randomly sampled, hood density may vary quite significantly even on the same day.

According to the results, the hood density increased from below 20 hoods per square meter in April to reaching a maximum of over 50 hoods per square meter in May. It then declined continuously from May to about 25 hoods per square meter in August.

The hood to burrow ratio rose steadily from below 1:0.2 to over 1:0.6 in July. It then decreased to about 1:0.5 in August. This implied that, given that all *A. lactea* have to live in burrows to survive, they were more likely to build hoods in July and August. As the reproductive season of *A. lactea* was between June to August, the extremely high density of hoods in May might be also due to factors other than reproduction. The hood density then decreased as it approached the end of reproduction period in August.

It was found that the hood to burrow ratio in May was closer to 1:1 and its hood density increased. The higher proportion and density of hoods may imply that the importance of hoods increased in the midst of reproduction period.

It was proposed that the abundance of hoods accurately indicates the intensity of mating, as in *U. terpsichores* (Christy et al., 2001) and *U. leptodactyla Rathbun*, 1898 (Masunari, 2012). However, burrow and hood densities are related to surface activities, which are related to biotic functions such as feeding, availability of food, agonistic behaviour, predation and recruitment. They are also related to abiotic features such as substratum preference, harsh conditions (rise and fall in temperature), tidal periodicity etc. (Skov & Hartnoll, 2001)[6]. The hood to burrow ratio can be easily affected by many factors other than reproduction. The importance of hoods in mating should be determined when taking other abiotic and biotic factors into consideration.

5.3. Discussion on Objective 3 – To study the relationship between hood size and size of male *A. lactea*

Generally speaking, the size of the hood built, in terms of the length, width and height, has a slight correlation with the width of the carapace of the *A. lactea*. From graph 1 - 3, the length, width and the height of the hood built increased with the width of the carapace of the fiddler crab. Yet, the 3 parameters has a difference in the strength of correlation with the width of carapace. The length and the width of the hoods have a stronger relationship with the size of the carapace of *A. lactea*, while the height of hoods is less related comparatively. Most of the crabs we captured have the carapace length around 14-16 mm which resulted in more or less the same size of hood. The sample size is smaller further lower the value of r square.

As the size of hoods generally increased with the carapace of the *A. lactea*, and with the fact that male fiddler crabs of larger size tend to attract female and carry out reproduction more easily [4], this may show that having a larger hood is one of the ways for a larger *A. lactea* to acquire a stronger competitive edge to attract females, thus proving that a larger hood could facilitate manoeuvring. With the ability of attracting females, the male fiddler crabs could copulate with the females attracted. Thus the presence of hoods could facilitate reproduction of fiddler crabs.

5.4. Discussion on Objective 4 – To investigate the reasons for the hood-building behaviour of *A. lactea*

There were few observations reported that the males with hoods had successfully attracted females to go into the burrows throughout the time of our field studies. According to literature, when female crabs enter the male burrows, reproduction may take place. No female crabs were reported to have entered male burrows without hoods in our field studies. It is likely the hood is built for the purpose of reproduction as suggested.

However, the results from the iron cage did not support such idea.

In the set-up with male and female crabs, no hoods were found and it suggested the presence of female did not trigger the hood-building behaviour of male fiddler crabs Nevertheless, no hoods were found also in male-only set-up. The absence of hood built by male crabs may be due to small sample size. Individual differences may be large. Second, as random male crabs are captured and put in the cage, the male crabs may not necessarily reach sexual maturity and no hoods were

[6] Burrow morphology of three species of fiddler crab (Uca) along the coast of Pakistan (https://www.academia.edu/7404793/Burrow_morphology_of_three_species_of_fiddler_crab_Uca_along_the_coast_of_Pakistan)

found.   Thirdly, the crabs may be still adapting to the new environment even though we tried to revisit the cages after two weeks. Since the set-ups include the placement of the cages. Even though the soil inside the cages was obtained from the site itself, the cages were placed on the ground instead of being partly immersed in the soil. Thus, the nutrition level, oxygen content and water content may vary from the original habitat after some time. Fourthly, there was a slight decrease in number of crabs after two weeks. This indicated that the crabs could escape from the cage and there was also chance that some crabs outside the cage could enter the cage through the aperture. This could be shown by the figure showing the soil beneath the cage after the experimental set-up was removed. There were three burrows shown in the figure (marked by red circles in Figure 20). As the crabs could escape through the burrows, this decreased the reliability of the set-up. Two lone claws were found in the control set-up. Since *A. lactea* are able to regrow claws, the lone claws might be left behind by crabs that had successfully escaped. Moreover, the soil inside the cages might not provide enough nutrition for all of the crabs so that some crabs might have been outcompeted for resources and eventually died. The dead bodies might been composed in the time the set-ups were left alone. Owing to limited time, replications were not allowed and the reliability of the results is low.

According to a research, male fiddler crabs (UcaLeach, 1814) are known to build mud or sand structures at the entrances of their burrows and females would orient to these structures when seeking mates[7]. Another research suggested that semidomes (hoods)   in *Uca lactea* (de Haan, 1835) , which was the previous name of *A. lactea,* have been found to attract females to males' burrows for mating[8]. As Crane (1975) noted, females of all hood-building species investigated (including *A. lactea*) follow males into their burrows for mating. Hoods may therefore function as sexual signals to which females orient visually[9].

Besides, a scientific study shows that unless female *U. lactea (A. lactea)* are exposed to a mock predator, they are attracted to semidomes only during the reproductive period when females are seeking mates[10]. The lack of hoods in both set-ups might be due to the fact that the reproduction period had already passed.

The number of male crabs in the experimental set-up was fewer than that of control set-up, but the number of burrows in the experimental set-up was more than that of control set-up. There were two possible reasons for this observation. Firstly, one burrow might contain more than one opening, the fiddler crabs are occupied two or more openings. However, due to the soft texture of soil, the mass movement of digging destroys the soil underground that we are not able to observe the access of burrows to other pathway. Secondly, one male crabs might dig more than one burrow. An improvement can be done by taking time-lapse video to track the crab behaviour to further support the reason we have suggested.

In a scientific paper [2], it was suggested that hoods are built for defence against wandering male *A. lactea* from the builder's burrow. Therefore, we would also like to justify whether the statement is true or not. Theoretically, a higher hood to burrow ratio meant a higher chance to build hoods for each burrow and a higher crab density meant a higher number of potential competitors. However, from our results, there was no clear relationship between hood to burrow ratio and crabs density. The

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[7] Hood-building dynamics and mating mode in the temperate fiddler crab Uca uruguayensis Nobili, 1901 (https://pdfs.semanticscholar.org/7a00/8709b74c1e4c8af02bef887d10329510771f.pdf)

[8] Hood building and territory usage in the fiddler crab, Uca lactea (De Haan, 1835)(https://www.researchgate.net/publication/303426607)

[9] The fiddler crab, Uca bengali Crane, 1975: Population biology and burrow characteristics on a riverbank in southern Thailand (https://www.researchgate.net/publication/281629267_The_fiddler_crab_Uca_bengali_Crane_1975_Population_biology_and_burrow_characteristics_on_a_riverbank_in_southern_Thailand)

[10] A mechanism for visual orientation may facilitate courtship in a fiddler crab https://www.sciencedirect.com/science/article/pii/S0003347214004606?via%3Dihub

average hood-burrow ratio in April was lower than that in May while the crab density in April was higher than that in May. Therefore, given that with more intense competition in May, the crab density is high, indicating that there is no higher tendency for the crabs to build hoods. From this result, the hoods were not used for defence.

To sum up, the reasons for building the hood by male crab is not clear. Though a lot of research papers have proposed different ideas, we failed to repeat their work due to limitations of the design of our set-up. The limited sample size and time further inhibited us to get a reliable and consistent results to make a solid conclusion.

5.5 Discussion on extra findings

The compactness of the soil in the experimental set-up was higher than that in the control set-up. Based on a research[11], it was found that the soil compactness influences the burrow depth. Burrows in clay-rich mudflat were the deepest while those in sand flat were the shallowest. This could explain the limitation of our experiment - the reason for the presence of burrows beneath the cage, which are shown in figure 20 after the cage was removed. The compacted soil in the experimental set-up allowed the fiddler crabs to dig more deeply, resulting in the loss of crabs after the experiment after they found a way to escape from the bottom of the cages.

In addition, the soil in the experimental set-up showed a dark grey colour while that in the control set-up did not. Normally, anaerobic condition is a result of water-logged soil and thus a lack of air circulation. However, from observation, the water content in the soil of two set-ups did not show a significant difference. Besides, as the two set-ups were located in the same environment, there should not be inundation of water in only one of the set-ups.

According to other scientific research, in the process of building burrows, fiddler crabs benefit the marsh by aerating the soil and bringing organic matter to the surface. As they sift through the sands while feeding, they aerate the substrate and prevent anaerobic conditions (decay without oxygen present)[12]. Another research revealed that fiddler crabs, through their burrowing activity, translocate oxygen into the anoxic layers and promote aerobic respiration, iron reduction and nitrification. The subsurface layers of burrowed sediments were significantly oxidized by the crabs' burrowing activity.

Therefore, although there were fewer male *A. lactea* in the experimental set-up, the burrowing activity was higher than the control set-up as more borrows were found. This was contradictory to the research mentioned above as more burrows should lead to more aerobic soil. Further investigation is required to find out the reasons of the condition that anaerobic soil was only found in the experimental set-up and whether there is a relationship between hood-building and oxygen level or texture of the soil.

5.5. Further investigation

1. Why would the number of female *A. lactea* always far lower than that of male?
2. How is hood-building behaviour affected by the environmental factors such as relative humidity, wind speed, wind direction, water salinity and pollution level?
3. How would *A. lactea* respond when their hoods were destructed?
4. How can *A. lactea* use the hoods for defence against potential competitors?

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[11] The relationship between intertidal soil composition and fiddler crab burrow depth, https://static1.squarespace.com/static/580e3c475016e191c523a0e2/t/586a6d83f7e0abf6d547677f/1483369862402/Chen+et+al.+2017.pdf
[12] https://gcrl.usm.edu › public › gulf.creatures › fiddler.crabs.php

5. Does the shape and inclination of the hood built follow any specific pattern?
6. According to lead author Tae Won Kim from the Korea Institute of Ocean Science and Technology[13], fiddler crabs have terrible eyesight, so a male on a trip must remember the way back to his burrow. Can *A. lactea* recognize the correct way to their own burrows by building hoods?
7. From the extra findings, the anaerobic soil was only found in experimental set-up. What is the reasons and will this affect the hood building habit of *A. lactea?*

CONCLUSION

The male to female ratio of *A. lactea* increases from April to August, showing that females are more active during reproductive season. The hood to burrow ratio generally shows an increasing trend from April to August while the hood density increased from April to May but decreased afterwards. Both male and female crab density show a similar trend as the hood density. Thus, crab density is more related to the hood density than it is to the hood to burrow ratio. The larger size of male *A. lactea* is also related to a larger hood size. According to our observation, hood-building behaviour favours mating but the iron cage set-ups failed to prove this hypothesis.

[13] Earth - Crabs build 'temples of love' http://www.bbc.com/earth/story/20150218-crabs-with-hats-better-mates

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