Biology IA

Research question:
Is there a significant difference in the claw and carapace lengths of male porcelain fiddler crabs (*Uca annulipes*) at the fore mangrove compared with the back mangrove?

The "fore mangrove" is considered as the area directly adjacent to the low waterline of the river in the mangrove forest, whilst the "Back mangrove" is an area further in towards the land in the mangrove forest. This location was approximately 35m inland from the waterline for this experiment.

Background information:
Pulau Tioman is a Malaysian island in the South China Sea, with a latitude of only 2.8 degrees north[1]. With it being so close to the equator, it has a tropical rainforest climate with lush mangrove forests as well as coral reefs. I have carried out this experiment in the mangrove forests of this island studying male *Uca annulipes*, which are also known as porcelain fiddler crabs. These crabs are detritivores that sift through sand in order to find sedimental detritus, left behind by the receding tides[2]. The males of this species have one enlarged claw that is used to attract females of its species, where larger claws are considered to be more attractive. These fiddler crabs can be found in the mangrove both next to the river and away from it, and I have decided to look for differences in claw and carapace size depending on the distance from the river. Distance from the river is an abiotic factor that could potentially affect the claw and carapace sizes of these crabs, which is the independent variable of this experiment.

Hypothesis:
The location that is further away from the river (Back mangrove) will have male porcelain fiddler crabs that are larger in both carapace size and claw size compared with the location that is adjacent to the river at low tide (Fore mangrove). Since it takes some time for the rising tide to reach the back of the mangrove, and the back gets uncovered first by the receding tide, crabs at the back mangrove will be spending a larger proportion of their time on the surface compared to crabs at the fore mangrove. This might allow them to look for food for a longer time, resulting in larger claw and carapace sizes.

Personal engagement:
When we were given a tour of the mangrove on the day we arrived on Tioman, I saw a large number of fiddler crabs by the first river we crossed. However, these crabs were also present a good distance into the mangrove forest, far away from the river. This made me wonder if these crabs located so far away from the river got the same amount of resources available to them, such as food and area for habitat. I thought that a good way to look at these factors was its carapace size, as organisms tend to be larger the more food and space they have available to them. However, I thought that looking at just its carapace size would not be sufficient, so I have decided to limit the crabs I measure to males, and also measure the length of their iconic giant claw, which they wave around to attract females and intimidate other males. Since this claw is only useful for attracting females, only crabs that have access to extra food and space on top of the amount they need for survival will be able to spend their resources growing it. By

[1]"Pulau Tioman, Malaysia." Geographical Names.
[2]"Fiddler Crab." Wikipedia.

measuring claw sizes in conjunction with carapace sizes, I will be able to have a better idea of the amount of resources these crabs have available to them. During the actual data collection, I have encountered many difficulties due to the crabs being harder to catch than expected, but I have managed to collect all the required data despite staying at the location for longer than expected.

Independent variable:
Distance from the river at low tide in the mangrove (Front & Back mangrove)

Dependent variable:
Length of the larger claw on male porcelain fiddler crabs (mm), length of its carapace (mm)

Controlled variables:
-Gender of the crab
Only male fiddler crabs are captured and measured

-The claw that is measured
The larger, enlarged claw is measured

Variables that could not be controlled, but were monitored:
-Vegetation in the area
Plants such as mangroves or seaweed that could be present in the area

-Other animals in the area
Organisms such as other species of crab, or animals that prey on the fiddler crab

-Temperature of the area

Equipment:
-Vernier caliper x1
-25m measuring tape x2
-1m x 1m quadrat x1
-Random number table for 0-25 x1

The uncertainty on the caliper is considered as ±0.10mm, as although it is able to measure to the nearest 0.02mm, the claws of the caliper may not have been aligned exactly with the claw due to difficulty in accurate measurement of the claw.

Method:
1. Set up a 25m x 25m sampling grid at a location adjacent to a river at low tide with fiddler crabs present with two tape measures. This location is the "Fore mangrove", which is the side of the mangrove that is adjacent to the river. Record any qualitative data observed.
2. Using a 0-25 random number table, find a coordinate within the sampling grid and place the bottom left hand corner of a 1m x 1m quadrat at that location.

3. Pick up and measure the length of the claw and the length of the carapace (does not include legs) of any male porcelain fiddler crabs (*Uca annulipes*) present within the quadrat using the Vernier caliper. Only males have an enlarged claw, so this feature can be used to distinguish males from females. There may be species of orange fiddler crabs (*Uca vocans*) in the area as well, which have orange pimply claws, so make sure not to measure these. The features of the porcelain fiddlers that are being investigated include: a square-like body, white or pink pincers, and a dark body with white stripes[3]. Record your data.
4. If there are any crab holes with small balls of sand around it within the quadrat, there is a possibility that there is a crab inside the hole. Dig in your finger next to this hole and gently push up the crab from underneath with your finger. Measure its claw and carapace length using a caliper if it is a male. Record your data. Take care not to harm the crab whilst doing this.
5. Repeat steps two and three until a minimum of 10 male porcelain fiddler crabs have been measured at the location.
6. Repeat steps one to five at a location further in towards the land from the river, approximately 30m away. This location will be the "Back mangrove", which is the side of the mangrove that is further away from the river. Record any qualitative data observed at the new location as well.

The data for the claw and carapace lengths obtained at these two locations will be analyzed using the student's t-test to see if there is a significant statistical difference. If there were a significant statistical difference, it would mean that there is a high possibility that the differences are not due to chance, allowing me to conclude that the differences in biotic/abiotic factors at the two locations may have an effect on the sizes of porcelain fiddler crabs. Random sampling in a 25m x 25m sampling grid is used at the two locations in order to prevent human bias, and a minimum of 15 values should be collected for both claw and carapace length at each location in order to have a reliable set of data for the student's t-test. Random sampling at two locations was chosen over the transect method for testing the relationship between distance from the waterline and the size of crabs, as the distribution of crabs in the area was rather uneven, so there would have been many quadrats with no crabs present if the transect method was used, resulting in a data set that is hard to work with.

Safety

When working with the fiddler crabs, uttermost care is taken in order to minimize the harm done to them. Their sizes should be measured while they are on the ground when possible, and they are picked up only when necessary. When attempting to dig one up, dig next to its hole and slowly lift it out. Try to repair its hole if possible, and release the crab right where you found them after measuring them.

[3]"Porcelain Fiddler Crabs (Uca Annulipes) on the Shores of Singapore." Wildfactsheets.

As for the safety of the person carrying out the research, there is the possibility of cuts caused by marine debris such as glass, metal or sharp plastics that often get trapped in the roots of mangroves. Fiddler crabs can also pinch rather strongly with their claws when agitated, resulting in injury. Both of these hazards can be avoided by wearing protective clothing (Long sleeves, trousers and proper shoes) and gloves when carrying out this experiment. You may also encounter animals such as monitor lizards and macaques in the mangrove, which are usually not aggressive, but it is best not to agitate them for your safety.

Raw data

Figure 1: Table showing claw length and carapace length of male porcelain fiddler crabs at the fore mangrove

Crab number	Length of claw (mm) (±0.10mm)	Length of carapace (mm) (±0.10mm)
1	30.52	17.36
2	28.24	15.10
3	27.24	15.58
4	33.82	23.04
5	29.14	16.52
6	31.88	17.00
7	30.42	21.96
8	38.64	25.02
9	45.26	27.80
10	33.12	18.04
11	25.98	17.24
12	23.50	18.12
13	26.42	16.72
14	31.74	17.88
15	28.68	16.60

Qualitative observations:
-Location is right next to a river that is connected to the sea, at low tide
-Not many plants in the area
-No canopy cover, bright sunlight
-Sand contains dead organic matter such as branches and leaves
-Sand is clay like and moist
-Other species of crab not observed
-Fiddler crabs are rather aggressive, trying to pinch your finger and escape

Figure 2: Table showing the claw length and carapace length of male porcelain fiddler crabs at the back mangrove

Crab number	Length of claw (mm) (± 0.10mm)	Length of carapace (mm) (±0.10mm)
1	15.68	15.02
2	18.24	16.40
3	22.52	18.96
4	16.72	14.04
5	20.22	16.42
6	18.04	19.32
7	27.54	19.86
8	27.82	18.50
9	32.76	26.12
10	26.44	18.04
11	15.52	12.28
12	22.50	17.84
13	18.56	15.20
14	33.26	17.22
15	19.82	17.38

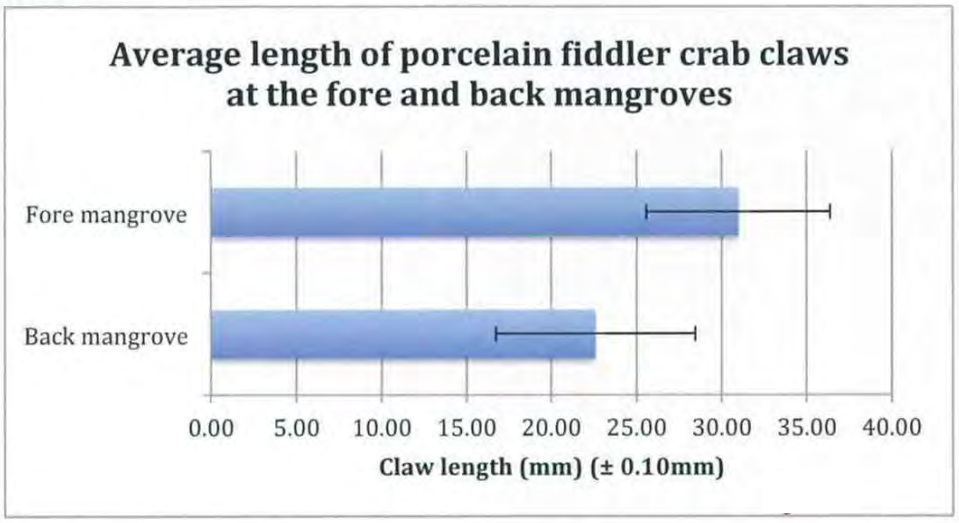
Qualitative observations:
-Location has a small stream of salt water running through it
-Lots of vegetation in and around the location
-Mangrove trees with pencil roots present
-Some canopy coverage of the sky resulting in shades
-Sand is very watery
-Other species of crab present as well (orange fiddler (*Uca vocans*), Large black crab with light blue underside)
-Crabs are less aggressive when picked up compared to ones at the fore mangrove

Processed data

Figure 3: Table showing average and standard deviation of claw and carapace lengths at the fore mangrove and the back mangrove

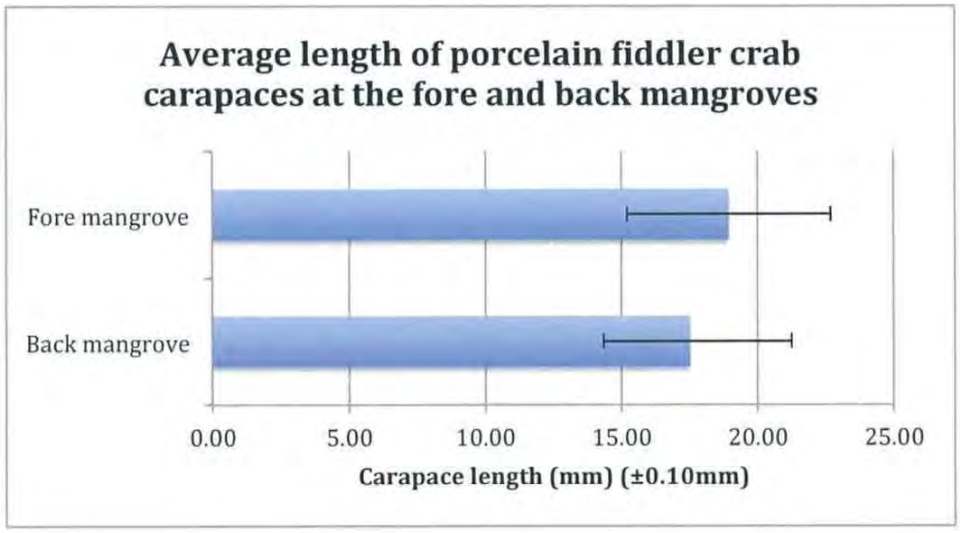
	Claw lengths		Carapace lengths	
	Fore mangrove	Back mangrove	Fore mangrove	Back mangrove
Average (mm) (± 0.10mm)	30.97	22.59	18.93	18.05
Standard deviation (mm)	5.41	5.86	3.74	3.35

Figure 4:



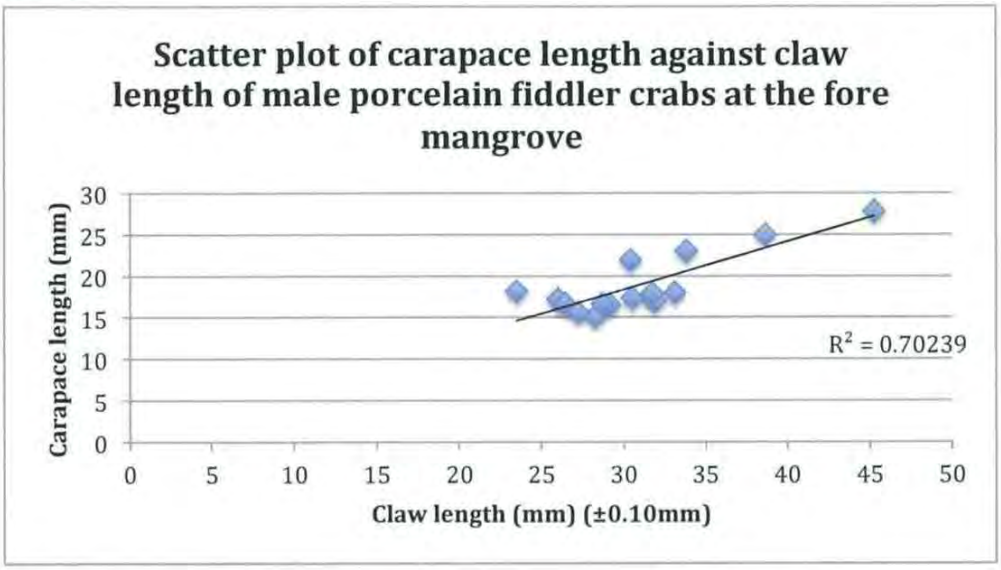
The average claw length of male fiddler crabs is much higher in the fore mangrove compared to the back mangrove. There is a slight overlap in the error bars due to the standard deviation being quite high for lengths at both locations, but a clear difference can be seen.

Figure 5:



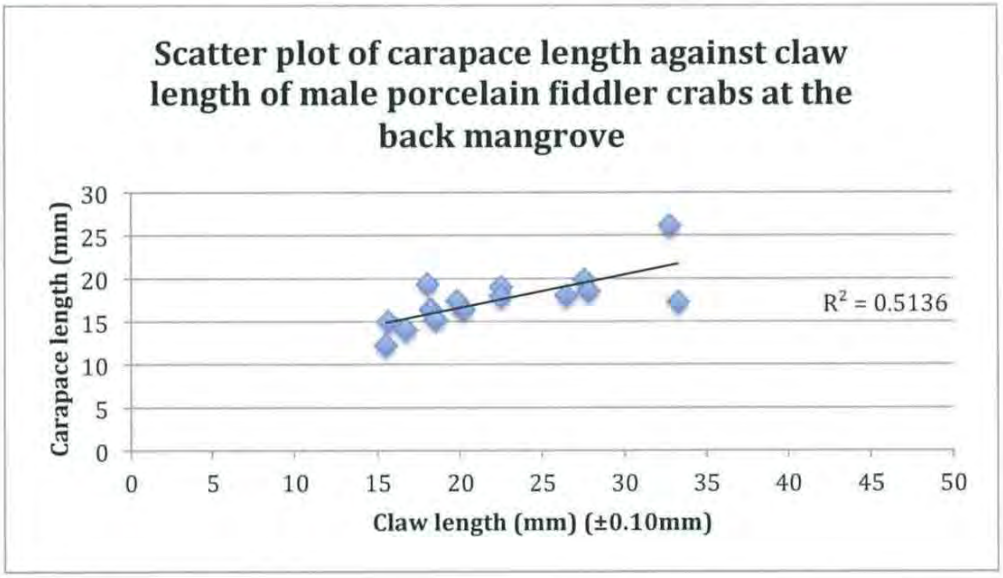
The average carapace length of the fiddler crabs is longer in the fore mangrove compared to the back mangrove, but only but a small amount. There is also a major overlap in the error bars, meaning that there may be very little actual difference in the lengths at the two areas.

Figure 6:



There is a strong positive correlation between carapace lengths and claw lengths at the fore mangrove: the larger the carapace, the larger the claw. This can also be seen from the Pearson's correlation coefficient of 0.84 (square root of R^2), which indicates a very strong positive relationship. There is a high concentration of crabs with a 15-20mm carapace and a 25-35mm claw.

Figure 7:



There is a positive correlation between carapace and claw lengths at the back mangrove as well, although the correlation is not as strong as it was in the fore mangrove. The Pearson's correlation coefficient (square root of R^2) is 0.72, which is still considered a strong positive relationship. The points are quite evenly spread out, and it can be seen that the claw lengths at the back mangrove are smaller in general when compared with the plots on figure 6.

Student's t-test:
As mentioned before, the student's t-test will be used in order to test if there is a significant statistical difference between the claw and carapace lengths of male porcelain fiddler crabs at the fore and back mangrove.
The null hypothesis for this test is "There is no significant statistical difference between the claw lengths of the porcelain fiddler crabs at these two locations" and "There is no significant statistical difference between the carapace lengths of the porcelain fiddler crabs at these two locations". Putting the set of claw length and carapace length data (figures 1 and 2) at the two locations through the t-test allows us to see whether the respective hypothesis still stands.

Figure 8: Table showing the p values as the result of a t-test for both the claw length and carapace length of male porcelain fiddler crabs at the fore and back mangrove

	Claw length	Carapace length
P value	0.000319	0.503

Data sets with a p value of below 0.05 is considered to have a significant statistical difference between them, as there is at least a 95% possibility that these differences are not due to pure chance.

From these p values obtained through the t-test, the null hypothesis can be rejected for the claw lengths, as it is well below the critical value of 0.05, at 0.000319. The p value it too high for the null hypothesis for the carapace lengths to be rejected, at 0.503, so this one will still stand.
From these results, these two statements can be made:
-"There is a very highly significant statistical difference between the claw lengths of male porcelain fiddler crabs at the fore mangrove and the back mangrove"
-"There is no significant statistical difference between the carapace lengths of male porcelain fiddler crab s at the fore mangrove and the back mangrove"

Conclusion
The aim of this experiment was to investigate how distance from the low water line affects the growth of porcelain fiddler crabs, by testing if there was a significant statistical difference in the claw and carapace lengths of male crabs at a location adjacent to the river at low tide (fore mangrove) and a location further in towards the land (back mangrove). Based on my biological knowledge on these fiddler crabs and some deduction, I have hypothesized that porcelain fiddler crabs near the back of the mangroves would be larger in both claw and carapace size due to it having more time to feed.
From the data that has been obtained (Figure 8), it can be said that there is a very highly significant statistical difference in the claw lengths of male porcelain fiddler crabs at a location that is adjacent to the river and a location that is further away from the river, with the location that is nearer to the river having porcelain fiddler crabs with larger claws. No major difference in carapace size can be observed. This is not what I have expected in my hypothesis, as I thought crabs would be generally larger at the back mangrove. However, the data that

supports this conclusion is pretty strong. A p value of only 0.000319 (Figure 8) means that there is just a 0.0319% possibility of the claw sizes being different due to chance, which is very unlikely. This difference was also very apparent when the actual measurements were being done at the locations in the mangrove, as the crabs at the fore mangrove had obviously larger claws than those at the back mangrove, which can also be seen from the average claw length of 3.08cm at the fore mangrove compared to 2.24cm at the back mangrove (Figure 3). There is also not too much overlap in the range of data collected for the claw lengths, as seen from the error bars on figure 4. As for the carapace lengths, both the p value of well over 0.05 and the overlap of the error bars on figure 5 suggest strongly that there is no significant statistical difference between the two locations.

The relatively strong positive correlations between claw and carapace lengths of male porcelain fiddler crabs at both locations suggest how crabs with a bigger carapace tend to have bigger claws. This is seen from the Pearson's correlation coefficients of 0.84 (Very strong correlation) and 0.72 (Strong correlation) (Figures 6 and 7) for the fore and back mangroves respectively. All the points lie close to the trend line, meaning that there weren't any male crabs measured that had a unusually big claw with a small carapace, or vice versa. From this, it can be inferred that these crabs don't "bluff" their claw sizes, where they spend all their resources such as nutrients in order to grow their claw to attract females, whilst actually being small in body size. Although I have used a random sampling grid when collecting data in order to reduce human bias, I may have unintentionally collected larger crabs due to them being easier to notice within the random quadrat.

Since we know that the difference for claw size was probably not due to chance from the p values obtained from the t-test, it would mean that it could be due to the environment they live in. One major reason that the porcelain fiddler crabs at the fore mangrove had much larger claws than the ones at the back mangrove could be due to interspecific competition in the back mangrove. As far as I have observed, there were no other crab species at the fore mangrove other than the porcelain fiddler crabs (*Uca annulipes*), but there were other, much larger crabs present at the back mangrove such as orange fiddler crabs (*Uca vocans*)(Figure 1). Competition with these larger species of crab could have made it much more difficult for the crabs at the back mangrove to obtain food or enough space for their hole in order to grow a large claw. The fiddler crabs found at the fore mangrove were also more aggressive compared to the ones found at the back mangrove, as they tend to pinch your finger and stab with the nails on their feet in an attempt to escape. The fiddler crabs at the back mangrove did not do much of this, which could mean that they are more passive and thus can not get as much food or space for habitat as the ones found at the fore mangrove.

The general area of the mangrove that I have surveyed was rather flat, with not much inclination of the ground. This would mean that the back and the front would get flooded with the rising waters of the tide, and would resurface again with the receding tide, at around the same time. Therefore, it would mean that the time the fiddler crabs get in order to look for food would be around the same, which would explain why my hypothesis was incorrect.

Evaluation

Having sampling grids in two distinct locations, one that is right next to the river, and one that is as far away from the river as possible, was well suited for this experiment. Since a lot of data can be collected at each location compared to the transect method, it allowed me to get a solid set of data on the sizes of the crabs in the area, and also use the student's t-test to check if the difference is statistically significant. Although the gradual change in claw and carapace sizes can not be seen with increasing distance from the river, taking two locations at the extremes should give me a good idea of how size changes. The use of the random sampling grid also helps reduce human bias, as I may only pick and measure crabs that match the size that I am expecting if this was not used. Measuring both the claw and carapace length has allowed me to plot these two values against each other in order to look for correlations between them, which would not have been possible of only the claw length was measured. Just the carapace length does not define everything about the crab, but it gives us a general idea of how big that individual crab was.

As with many investigations in the ecological field, there were many causes for error in the experiment. Although the data I have collected suggests that there is a significant difference in claw size and no significant difference in carapace size at the two locations, there were many flaws in the experiment that may have affected these results.

Error/limitation	Significance of error	Improvements
1m x 1m quadrat is not placed exactly at the coordinates, since the coordinates are found within the grid by having people walk from the x and y axes and marking where they meet	The coordinates could be off by as much as a few meters due to people not walking straight. This random error is not that significant in this case, since you are looking for a random location anyways. However, this could potentially result in the same location being sampled twice, which could result in incorrect data.	All the grid lines for the random sampling grid at both locations can be drawn out on the sand beforehand in order to ensure the grid with the correct coordinates is sampled.
Abiotic factors such as pH of the sand, temperature, sunlight, and nutrient levels in the soil could not be controlled	This is not significant as the aim of this experiment was to see the change in size of these crabs with varying distances from the river. Although these factors are not directly relevant to the aim of this experiment, it is normal for them to change as you move away from the	All of these abiotic factors could be monitored at both locations with pH probes, thermometers and soil test kits and recorded in order to be able to relate any trends in the results to these values.

	river, so it is naturally a part of the experiment.	
Only 15 porcelain fiddler crabs were measured at each location	This is very significant, as it is recommended to have a minimum of 20 samples at each location when carrying out a student's t-test to get a reliable p value. 15 values is enough to get a general idea of the differences in the claw and carapace lengths, but it may not be an accurate representation of what is actually there.	More samples of male porcelain fiddler crabs could be measured at both locations in order to get a more reliable p value. This was not possible in this experiment due to time constraints, but it the results obtained would be significantly more reliable the more measurements are made at each location.
Limited porcelain fiddler crabs measured to only males	This is significant as in that it does not give me a complete view of the change in carapace size of porcelain fiddler crabs with varying distance, since females are not measured. However, it is insignificant when measuring claw sizes as well as the carapace size, since females do not have an enlarged claw that can be measured.	No modification has to be made in this case, as I am looking at both the claw and carapace sizes, which can only be measured on males. If looking at only carapace size, a greater number of samples from both genders would be required.
Not all male porcelain fiddler crabs found within the random quadrat were measured due to crabs escaping	This is rather significant as it means that I was unable to measure crabs that were fast at reacting or had a very cautious nature, which could potentially be a factor that would affect claw and carapace size. For example, crabs that are very cautious may not spend as much time as the other crabs on the surface to feed, resulting in smaller carapace and claw sizes.	I could try to dig up the crabs that have burrowed deep into their holes with a shovel, in order to make sure I measure every single male crab in the quadrat. However, this may not be the most ethical thing to do, as it would result in the destruction of the crab hole.
Species other than porcelain fiddler crabs (*Uca annulipes*) may have	This would have a very significant effect if other species were measured	A dichotomous identification key can be used on every fiddler

been measured as well, as I am not experienced with identifying crab species	as well, since crabs of different species naturally grow to different sizes independent of distance from the river.	crab sample in order to ensure that it is in fact *Uca annulipes* that is being measured, to prevent accidental measurement of other species.

Whilst carrying out this investigation, a few new questions came to my mind relating to these fiddler crabs. The first one is the possible factors that could affect the size of their carapace, if there are any at all. In my investigation, I could not see any significant statistical difference in the carapace size at the two locations, and their averages were very close to each other. I could carry out an investigation where I run a line transect from the river towards the inner mangrove, to see if there is any gradual change in carapace size with increasing distance from the low water mark of the river. This would allow me to have a larger sample size, as I can measure both males and females, and will also give me a better idea of the change in carapace size with distance from the river. Another possible investigation would be to look at the species distribution of crabs in an area and the effect it has on the claw and carapace sizes of porcelain fiddler crabs (*Uca annulipes*). In my investigation, the area that had many different species of crabs, as well as some plants, had porcelain fiddler crabs that were smaller than the areas that didn't have these. I have concluded that these differences could possibly be due to interspecific competition. In order to further clarify this, I can carry out an investigation looking at the correlation between the species distribution of crabs of a particular area of the mangrove and the claw and carapace lengths of porcelain fiddler crabs there. If my conclusion is correct, I would probably see that areas with a greater number of competitor species such as *Uca vocans* would have porcelain fiddler crabs with smaller claw and carapace sizes.

Bibliography

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International Baccalaureate
Baccalauréat International
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For first use in 2016 assessment

4/ICCS

Group 4: Individual candidate cover sheet (biology, chemistry and physics)

Arrival date: Session:

School number: School name:

- Complete this form in the working language of your school (English, French, Spanish).
- The form must be completed by the teacher and candidate.
- A completed copy should be retained by the school.

Subject: Biology Level: HL

Candidate name: Session number:

Candidate section:
To be completed by the candidate.

Title of the group 4 project: The ethics behind the theraputic use of embryonic stem cells

Write a reflective statement of about 50 words outlining your involvement in the group 4 project:

I have contributed to the Chemistry part of the practical by setting up the micro burette from the appartus provided, and carried out a number of the titrations myself.
For the video, I have written up the script from the research done by others in the group, and provided vocal narrattion for the video.
As a group, we had difficulties coming to an agreement on how we were going to approach our topic due to differing opinions on the topic, but once we got started on the actual project, we worked very well as a team.

Title of individual investigation: Is there a significant difference in the claw and carapace lengths of male porcelain fiddler crabs (Uca annulipes) at the fore mangrove compared with the back mangrove?