Candidate 1 evidence

An Investigation into the Effects of Temperature on the Cirral Beating Rate of Barnacles.

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Abstract

Aim:-
To investigate the effects of changing temperature on the cirral beating rate of barnacles.

Findings:-
As the temperature of the barnacles' surroundings was increased from 5°C to 25°C, in 5°C intervals, the cirral beating rate of the barnacles also increased. Cirral beating rate appeared to be at its greatest at the highest measured temperature of 25°C. As the temperature was increased from 5°C to 25°C, cirral beating rate increased by 182%.

Introduction

The scientific name, or Genus, of a barnacle is Cirripedia. It has the class Crustacea and the rank Maxillopoda and they belong to the Animalia kingdom. The phylum of a barnacle is Arthropoda and they have the higher classification, or Family, Thecostraca.

The entire intertidal zone is the fundamental niche of a barnacle and within this zone they compete with each other for room on rocks or whatever surface they have chosen to attach to. This means that competition between barnacles is mainly intraspecific[1]. However, there is interspecific competition between Semibalanus and Chthamalus which determines their realized niche, position on the rocks and zonation of the shore.

Barnacles are an R-selected species meaning that they produce large numbers of offspring during their lifespan as they have lower chances of survival. As well as this, barnacles are simultaneous hermaphrodites meaning that they have both male and female reproductive organs rather than sequential hermaphrodites which are born as one sex and may change to the other at one point in their life. Barnacles are found all along the rocky shore and are usually attached to rocks but can sometimes be found attached to boats, shells or other animals like hermit crabs and sea snails. They can be preyed upon by gastropods which include sea snails, various types of fish, and a few different types of shorebirds.

A barnacle will feed on plankton and algae in the water and they do this by using small feeding appendages, known as cirri. The cirri brush through the water, filtering and collecting food for the barnacle. These cirri are also used for breathing as well as feeding. As the cirri are extended out to obtain plankton, they also help to obtain the barnacles oxygen supply.

There are numerous factors which can affect the distribution of barnacles along the rocky shore, including temperature, exposure and desiccation. In an area with higher temperature, there will be less barnacles present, however this is only the case in smaller volumes of water such as that in rock pools, as the temperature of the sea varies only slightly. As water temperature increases in a smaller volume of water in rock pools on hot days, this results in the water evaporating and the volume of dissolved oxygen in the water decreasing. When conditions are out with the tolerance of the barnacle, it will close its operculum and no longer cirral beat therefore being unable to obtain sufficient food and oxygen supply. Areas with particularly high temperature will also result in barnacles being more susceptible to desiccation when uncovered by water. Also, the further up shore the barnacles move, they will have a longer exposure time, resulting in a higher risk of desiccation.

As mentioned, temperature will affect a barnacle greatly. An increase in temperature of water in rock pools shall result in a decrease in the volume of dissolved oxygen in the water. Enzyme activity increases which will, in turn, increase the rate of metabolism and respiration. This uses up oxygen so the barnacle requires more, resulting in an increase in cirral beating rate. At the usual temperature of the barnacles' surroundings, cirral beating should remain steady as there is more dissolved oxygen in the water and a lower rate of metabolism and respiration.

A barnacle is a tough invertebrate, capable of withstanding harsh conditions, that is found in or close to sea water. Barnacles are sessile crustaceans which means that they cannot move by themselves and they are permanently attached to the object on which they live. As a juvenile, they are free-moving but they soon attach to a rock, shell, boat or even another animal such as a hermit crab.[2]
Barnacles are generally tolerant to an increase in salinity, however when salinity drops below approximately 25%, the barnacle will close its operculum. With regards to temperature, each species has a characteristic range in which most activity takes places. Beyond the normal range, there is a greater and smaller limit in which further change in temperature can be fatal. Open water has very little variation in physical properties, for example temperature, salinity and oxygen concentration. However, smaller volumes of water in rock pools can vary extensively in these factors. On a hot day, water in rock pools will evaporate and temperature of the water increases, resulting in less dissolved oxygen[3]. Under approximately 1.5°C, there can be some beating noted but when the temperature falls to around 0.5°C beating seems to stop completely. Beating appears to gradually increase as the temperature rises, however it also appears to cease at around 33°C[4]. At higher temperatures such as 25°C, there seems to be a rise in the rate of cirral beating whereas at lower temperatures like 5°C, there seems to be a decreased cirral beating rate[5]. Part of the justification of this investigation is to test the findings of this source.
It can be argued that respiration is restricted by the delivery of oxygen at higher temperatures as well as the barnacles' capacity to uptake oxygen at decreased temperatures. At higher temperatures, the volume of dissolved oxygen in the water decreases, resulting in an increase in cirral beating rate in order to obtain the required volume of oxygen. Therefore, in any case, temperature affects respiration which will, in turn, affect cirral beating rate. As temperature increases, so too does enzyme activity. This, in turn, increases metabolic rate and respiration which uses up oxygen, therefore the organism requires more. This results in an increase in cirral beating rate.[6]
In Millport, Hunterston Power Station is causing a large amount of thermal pollution. This is due to water being taken into cooling reactors within the plant and hot water being released back into the sea. This results in the heating of the surrounding water which will in turn cause many negative effects for the organisms which use the water as their habitat. Barnacles here will be greatly affected by the increase in the temperature of the water[7]. As well as corroborating the findings of this source, the investigation will be to gauge the impact of this thermal pollution on the barnacles on the shore of Cumbrae which is in close proximity to the source of the thermal pollution.

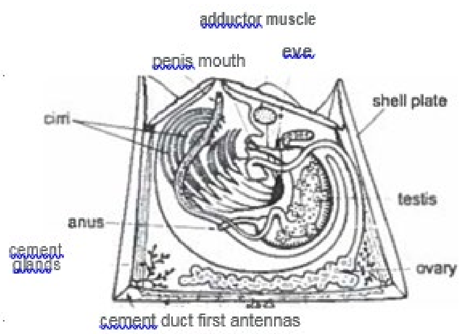
Aim: -

To investigate the effects of changing temperature on the cirral beating rate of barnacles.

Hypotheses: -

As the temperature is increased, cirral beating rate will also increase due to the barnacle needing more oxygen as metabolic demand increases due to increased enzyme activity.

Null Hypothesis - Changing the temperature will have no effect on the cirral beating rate of the barnacles.



Procedures

A pilot study was carried out in order to calculate a suitable sample size, to determine a range for the independent variable (temperature), how to measure the dependent variable (cirral beating rate) and also to determine confounding variables and an appropriate method of monitoring and controlling them. The results of the pilot study can be found in Appendix 1.

Method:-

Barnacles were collected from the rocky shore by systematic sampling through the use of a line transect. This involved collecting barnacles at regular intervals of every 5 meters along the shore. Small rocks with barnacle coverage were collected from the middle and lower zones of the shore that could be transported back to the lab. The equipment was set up before the experiment was carried out. The set up included a white tray containing seawater pumped from the barnacles' natural environment directly to the lab, in which the barnacles were fully submerged. A mounted magnifying glass was appropriately positioned in front of the tray in order to observe the barnacles more closely, making it easier to count the cirral beating rate. To increase the temperature, seawater was added to numerous beakers and placed into a water bath containing fresh water to heat up before being added to the barnacles' main water source in the tray. To decrease the temperature, tubes filled with water were frozen before being directly added into the tray containing the barnacles in their main water source. Temperature was measured using a thermometer, and maintained by regularly topping up with warm water, cold water or ice tubes which were chosen as they do not melt to decrease the salinity of the water.

Temperatures started at 5ºC and were increased in 5°C increments until reaching the highest temperature used, 25℃. As temperature was changed, the cirral beating rate was observed using the mounted magnifying glass and was measured using a click counter. The number of beats per minute were counted and this was repeated 3 times per barnacle at each temperature and the mean cirral beating rate for each barnacle was calculated.

After the results for the investigation were obtained, an independent replicate was performed. This involved repeating the experiment on another day, using different samples from a different shore on Cumbrae, approximately 2 miles away, on a different day, to obtain a separate data set. Control experiments are used to allow a comparison which proves that, in this case, it is definitely temperature which is affecting the cirral beating rate of the barnacles. The positive control for this investigation was using the temperature of the natural surrounding environment of the barnacle, however there was no negative control as it is impossible to have no temperature.

There were numerous confounding variables which had to be controlled and/or monitored throughout the investigation. The size of the barnacles was a confounding variable which was controlled by using barnacles of a similar size (approximately 0.5cm) measured by using a ruler in order to measure the barnacles' largest diameter.

Oxygen concentration was another which was monitored by using an oxygen meter when changing the temperature. Salinity was controlled by using water from the same source and also refreshing the water supply frequently and was monitored using a refractometer. Lastly, species of barnacle was a confounding variable which was controlled by using the same species of barnacle and checking with a suitable classification key. These confounding variables were controlled and monitored in order to ensure that there is only one variable (temperature) which makes the results valid as they *are* attributed to that factor.
A number of procedures and modifications were used during the investigation in order to improve the reliability and validity of results. It was discovered that large rocks would not fully submerge under the water, therefore smaller, flatter rocks were used to improve this. A rock map was used in order to avoid selection bias, this involved drawing the rock and plotting the barnacles on it. A random number generator was also used in order to decrease chances of selection bias when choosing barnacles to observe.

Procedure for Sample Size: -

An appropriate sample size for the investigation had to be worked out. This was done by measuring cirral beating rate of three barnacles to begin with, and the mean cirral beating rate was calculated. After this, cirral beating rate was measured for another two barnacles and a mean cirral beating rate was calculated before an overall mean cirral beating rate for all 5 barnacles was calculated. This was continued, using an additional 2 barnacles each time, until the mean would no longer change. The resulting sample size in this case was 7 barnacles. This sample size was then used in the investigation, therefore the cirral beating rate of 7 barnacles was measured at each temperature.

Monitoring of Salinity:-

Temperature (°C)	Salinity (%)
5	31
10	33
15	34
20	30
25	33

Monitoring of Oxygen Concentration:-

Temperature (°C)	Oxygen Concentration (mg/l)
5	9.1
10	8.7
15	8.4
20	7.9
25	7.0

Results

Investigation - Final Results Table

Temperature (°C)	Average Cirral Beating Rate (bpm)
5	11
10	13
15	21
20	22
25	31

It can be observed from the investigation results that as temperature is increased, the average cirral beating rate also increases due to less dissolved oxygen in the water and the barnacle requiring more due to an increase in activity of enzymes and metabolism.

Independent Replicate - Final Results Table

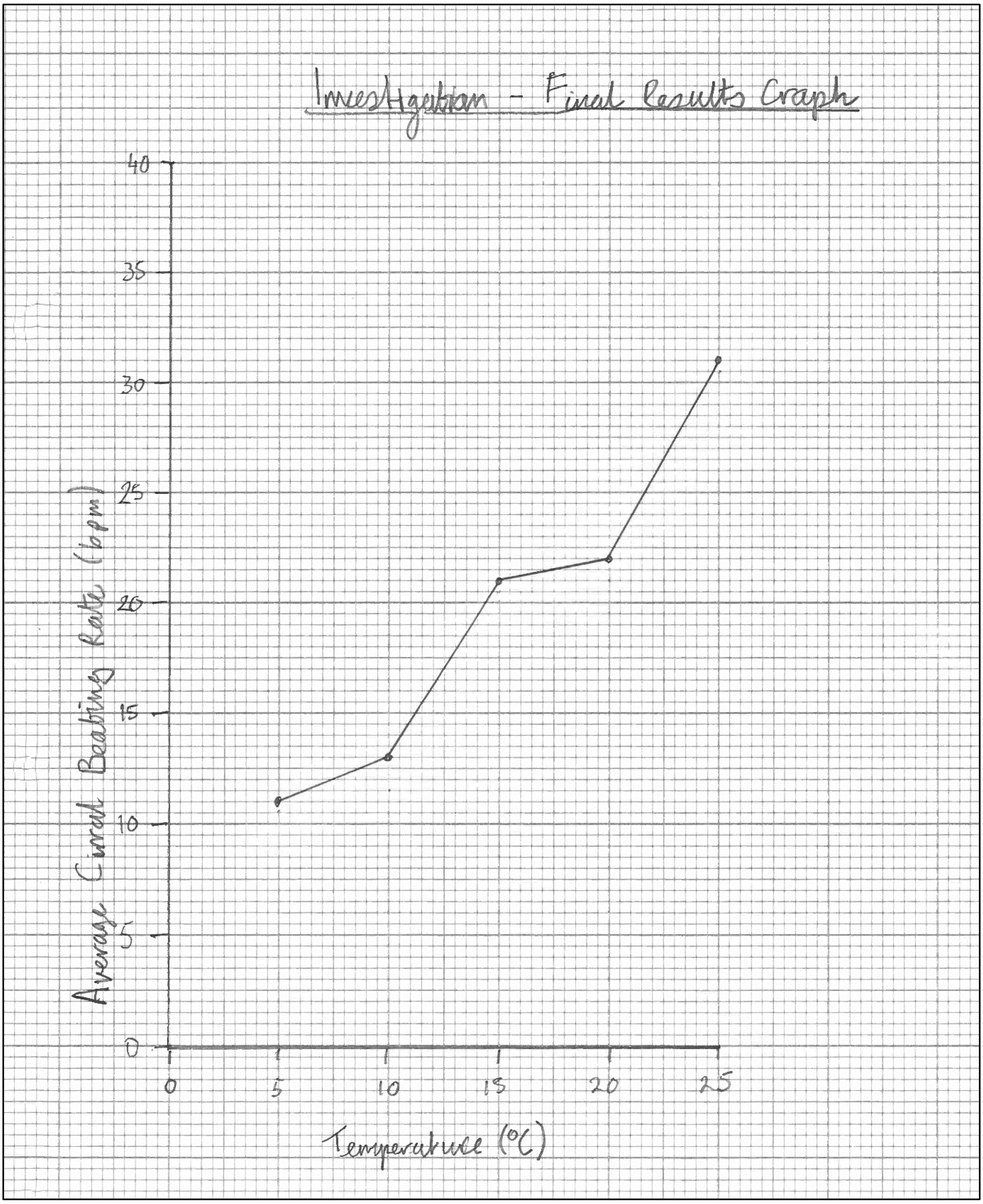
Temperature (°C)	Average Cirral Beating Rate (bpm)
5	9
10	14
15	20
20	22
25	31

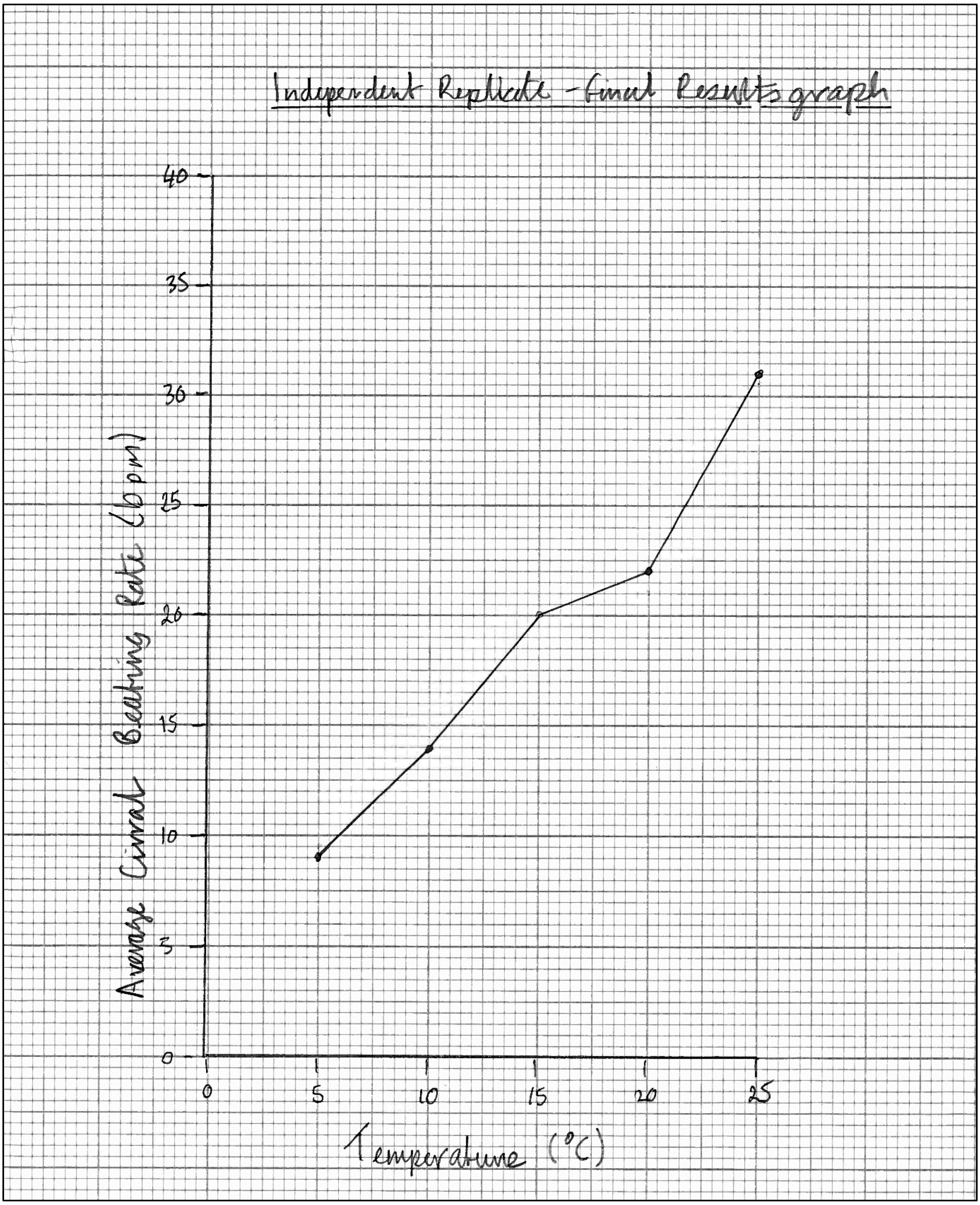
It can be seen that the independent replicate shows the same results as the investigation. As the temperature of the barnacles' environment is increased from 5°C to 25°C, cirral beating rate also increases.

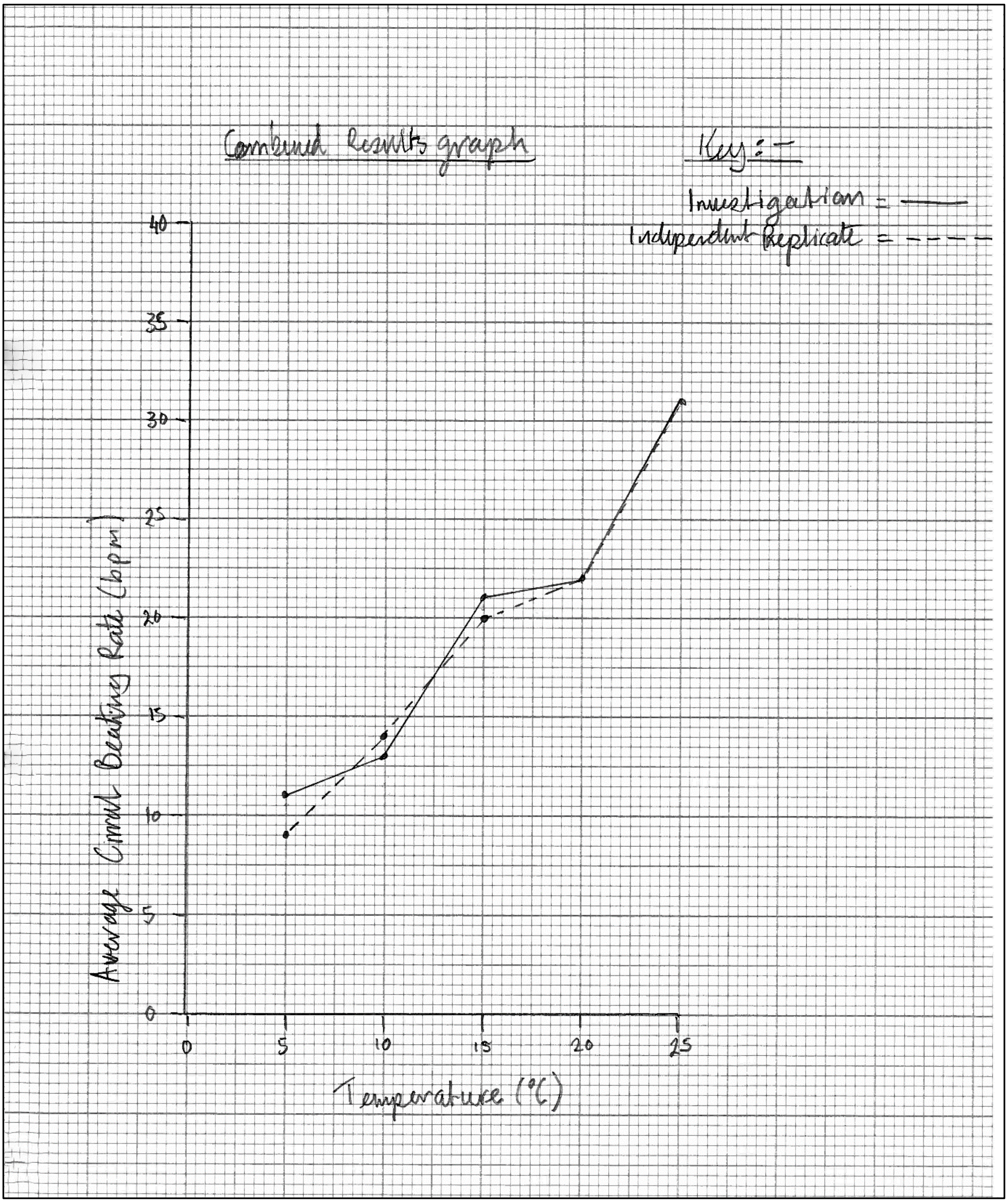
Combined Results Table

Temperature (°C)	Average Cirral Beating Rate (bpm)		
	Investigation	Independent Replicate	Overall
5	11	9	10
10	13	14	14
15	21	20	21
20	22	22	22
25	31	31	31

It can be observed that results obtained from both the investigation and the independent replicate are concordant with each other. Both results show that as temperature is increased from 5°C to 25°C, cirral beating rate also increases.


Investigation - Final Results Graph
Average Cirral Beating Rate (bpm)
40
35
30
25
20
15
10
5
0
0
5
10
15
20
25
Temperature (°C)


Independent Replicate - Final Results graph
Average Cirral Beating Rate (bpm)
40
35
30
25
20
15
10
5
0
0
5
10
15
20
25
Temperature (°C)


Combined Results graph
Key:-
Investigation = ———
Independent Replicate = - - - -
Average Cirral Beating Rate (bpm)
40
35
30
25
20
15
10
5
0
0
5
10
15
20
25
Temperature (°C)

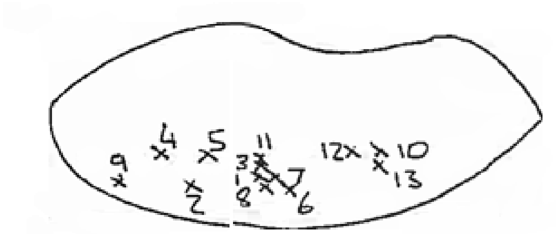
Conclusions & Evaluations

Conclusions:-

It can be concluded that increasing the temperature of the barnacles' natural environment does in fact increase cirral beating rate until an optimum is reached. As the temperature was increased from 5°C to 25°C, the cirral beating rate gradually increased. Cirral beating rate increased from 11 beats per minute to 31 beats per minute, resulting in an increase of 182%.

Evaluation of Procedures:-

A line transect was used when collecting barnacles from the shore. This involved the use of systematic sampling in which barnacles where collected every 5 meters along the rocky shore, allowing validity and the avoidance of selection bias.
In order to further avoid selection bias, a rock map was used which involved sketching the rock on which the barnacles were attached and then plotting the barnacles on the rock. As well as this, a random number generator was used when selecting barnacles to observe. The rock map helped to avoid choosing the same barnacle twice and the number generator helped to avoid selection bias. A picture of a rock map used is shown below.



Effects of confounding variables were recognized and monitored and/or controlled throughout, allowing accuracy and precision throughout the course of the investigation. Salinity appeared to remain relatively constant, with percentage of salinity values remaining relatively concordant with each other. This is important as it shows that differences in cirral beating rates are not due to changes in salinity. However, oxygen concentration appeared to gradually decrease as the temperature was increased. This confirms the fact that as temperature is increased, the volume of oxygen in the seawater decreases.
There was no negative control for this investigation as it is not possible to take away temperature therefore only a positive control was used, using the resting temperature of the barnacles' natural environment.
Cirral beating rate was measured three times before a mean was calculated and then an overall average beating rate was worked out. As well as this, an independent replicate was carried out which increased reliability of the results.
A number of modifications were applied to procedures in order to provide more reliable and valid data. Larger rocks could not be fully submerged under the water in the tray, therefore, to resolve this, smaller, flatter rocks were used throughout the experiment in order to be properly submerged in the water. A wider range of

temperatures were used in the investigation, in comparison to the pilot study, in order to obtain more reliable results. Ice tubes were used to decrease the temperature in order to avoid a decrease in the salinity of the barnacles' environment.

Evaluation of Results:-

From the results, it can be seen that the overall average cirral beating rate increases each time the temperature is increased. There is a low degree of variation between the results of the investigation and the independent replicate which highlights that the procedure was undertaken with a high level of precision. It also shows that there was a high level of accuracy in the procedures carried out during the investigation.
It can be observed that at 20ºC and 25°C, the mean cirral beating rate is the same value of for both the investigation and independent replicate, however this is not the case for results at the remaining temperatures which differ slightly. It takes time to properly measure the cirral beating rate of each barnacle, and the temperature of the barnacles' surrounding environment could have changed in this time due to the temperature of the room fluctuating, and this could be a possible explanation for the differing results.
The results from both the investigation and the independent replicate support the initial hypothesis that as the temperature was increased, the cirral beating rate of the barnacles would also increase as the barnacle needs more oxygen due to increase in metabolic demand and enzyme activity. The results refute the null hypothesis which suggested that cirral beating rate would be unaffected.
The findings highlight that the barnacles can withstand the slightly higher temperatures, as indicated by their higher cirral beating rate. This is because, at these higher temperatures, the barnacles have increased enzyme and metabolic activity resulting in an increased requirement for oxygen. This increased requirement coupled with a decrease in the amount of dissolved oxygen in the water results in the increase in cirral beating rate.
However, the barnacles cirral beating rate reaches a maximum at the optimum temperature of 25°C, therefore suggesting that if global warming continues, barnacles may not be able to cope with the increase in temperature of their surrounding environment in coming years.

References

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Cover picture - https: / / biol326.files.wordpress.com/2014/11/ semibalanus-balanoides-feeding-7-april-28-2007. jpg

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Appendix

Pilot Study Results:-

Lower Temperature (11ºC): -

Barnacle No.	Cirral Beating Rate (bpm)			Mean
	1	2	3	
1	18	20	17	18
2	47	19	58	41
3	44	41	48	44
4	17	19	19	18
5	17	24	21	20
6	32	37	34	34
7	54	43	49	49
Overall Average (bpm)				32

Temperature of Natural Environment (16°C):-

Barnacle No.	Cirral Beating Rate (bpm)			Mean
	1	2	3	
1	30	16	25	24
2	22	15	21	20
3	28	34	31	31
4	24	24	31	26
5	21	19	23	21
6	11	9	12	11
7	22	19	20	20
Overall Average (bpm)				22

Increased Temperature (21°C):-

Barnacle No.	Cirral Beating Rate (bpm)			Mean
	1	2	3	
1	57	32	30	40
2	33	32	35	33
3	49	51	48	49
4	37	40	33	37
5	34	33	45	37
6	33	41	35	36
7	42	47	47	45
Overall Average (bpm)				40

A result which was not the expected result was obtained in the pilot study, with cirral beating rate increasing with both an increase and decrease in temperature from the barnacles environmental temperature. A wider range of temperatures were used in the final procedures which may have accounted for the differing results of the pilot study and the investigation.

Raw Data:-

Investigation:-

Cirral Beating Rate at 5°C

Barnacle No.	Cirral Beating Rate (bpm)			
	1	2	3	Mean
1	11	14	13	13
2	8	10	8	9
3	11	10	6	9
4	12	9	12	11
5	9	7	11	9
6	15	10	13	13
7	12	12	10	11
Overall Average (bpm)				11

Cirral Beating Rate at 10°C

Barnacle No.	Cirral Beating Rate (bpm)			
	1	2	3	Mean
1	10	13	13	12
2	16	14	14	15
3	11	14	12	12
4	15	13	15	14
5	13	15	14	14
6	10	8	11	10
7	14	16	15	15
Overall Average (bpm)				13

Cirral Beating Rate at 15°C

Barnacle No.	Cirral Beating Rate (bprn)			
	1	2	3	Mean
1	21	24	19	21
2	21	21	25	22
3	22	22	19	21
4	23	19	17	20
5	21	24	20	22
6	19	23	20	21
7	23	25	19	22
Overall Average (bpm)				21

Cirral Beating Rate at 20°C

Barnacle No.	Cirral Beating Rate (bprn)			
	1	2	3	Mean
1	22	21	20	21
2	30	26	29	28
3	21	24	24	22
4	18	21	19	19
5	20	20	17	19
6	23	19	24	22
7	27	24	26	26
Overall Average (bpm)				22

Cirral Beating Rate at 25°C

Barnacle No.	Cirral Beating Rate (bpm)			
	1	2	3	Mean
1	33	31	32	32
2	28	29	34	30
3	39	41	39	40
4	27	24	29	27
5	26	31	28	28
6	32	28	34	31
7	29	32	27	29
Overall Average (bpm)				31

Independent Replicate:-

Cirral Beating Rate at 5°C

Barnacle No.	Cirral Beating Rate (bpm)			
	1	2	3	Mean
1	10	7	8	8
2	13	10	12	12
3	7	7	9	8
4	12	9	11	11
5	10	10	8	9
6	9	7	12	9
7	8	11	6	8
Overall Average (bpm)				9

Cirral Beating Rate at 10°C

Barnacle No.	Cirral Beating Rate (bpm)			
	1	2	3	mean
1	11	17	14	14
2	11	10	11	11
3	16	18	13	16
4	19	19	17	18
5	15	16	14	15
6	12	15	14	14
7	11	13	13	12
Overall Average (bpm)				14

Cirral Beating Rate at 15°C

Barnacle No.	Cirral Beating Rate (bpm)			
	1	2	3	mean
1	22	23	18	21
2	23	21	20	21
3	21	19	21	20
4	24	20	22	22
5	19	19	20	19
6	18	18	18	18
7	22	19	21	21
Overall Average (bpm)				20

Cirral Beating Rate at 20°C

Barnacle No.	Cirral Beating Rate (bpm)			
	1	2	3	mean
1	22	24	19	18
2	26	21	22	23
3	23	20	21	21
4	25	24	26	25
5	24	19	21	21
6	23	20	18	20
7	24	24	21	22
Overall Average (bpm)				22

Cirral Beating Rate at 25°C

Barnacle No.	Cirral Beating Rate (bpm)			
	1	2	3	mean
1	33	29	38	30
2	29	28	31	29
3	32	26	26	28
4	25	32	37	35
5	31	27	28	29
6	34	39	39	37
7	33	29	35	32
Overall Average (bpm)				31