Size of Barnacles Depending on Placement on Rock Surface

IB Biology Individual Investigation

I. Introduction

This year the biology students took a field trip to a beautiful island located on the western coast of Norway. There all students investigated the intertidal zone, learning about zonation and adaptation. The area's ever-changing and abundant life intrigued me, particularly the extreme abundance of some species, such as barnacles. This led me to do closer research into barnacles and what affects their growth.

The shoreline I investigated was exposed and experienced an extremely high wave velocity. Upon looking at both this shoreline and others in the area it would seem that the barnacles situated in less wave-exposed areas had a much higher density (see **Figure 1**), leading me to question if the strain of constant wave impact on the barnacles had a negative effect on their growth. To investigate this I inspected the difference in barnacle growth and density on two sides on the same rock: a more shielded, horizontal side and an exposed, vertical side.

Figure 1: *Showing the density of barnacles present on a less wave-exposed area* (Belamaric, 2021)

Figure : *Showing the Semibalanus balanoides, with an arrow pointing to their s-shaped groove. Also depicting juvenile (smaller and white) barnacles* (Photo by author, 2021)

Background information

Barnacles are crustaceans with traits similar to crabs and lobsters. They attach themselves to surfaces with one of the strongest natural known glues and live in places with high activity where they are protected by their hard calcium shells (NOAA, 2021). The barnacles inspected for this experiment were of the species *Semibalanus balanoides* L. They were identified by

their mirrored s-shaped groove (J. Ellrich, personal communication, June 17, 2021), which is their most prominent feature (**Figure 2**) (Hayward & Ryland, 2017). This species of barnacle attaches to surfaces and can grow up to roughly 15mm in diameter. It is found in intertidal zones throughout the North-East Atlantic and on the Pacific coast of North America. The barnacle is a filter feeder meaning that it extends feather-like "legs" called cirri while underwater. These filter zooplankton from the water which are then consumed by the barnacle (White, 2008).

Research Question

Is the size (longest diameter in mm) and percentage coverage of the barnacle species *Semibalanus balanoides* influenced by their position either approximately horizontally or vertically on an exposed rock?

Hypothesis

The *Semibalanus balanoides* placed on the horizontal surface will have a greater average size and density than those placed on the vertical surface. This being because there was an observed difference in density between places with high and low wave exposure. Therefore I anticipated that barnacles situated on the vertical side would be harmed by the strong and constant wave impact, thus not becoming as large and abundant.

Variables

	Explanation	Justification
Independent variable	The approximately horizontal or vertical surface of a rock.	
Dependent variable	Barnacle size (longest diameter in mm) and total coverage percentage of the barnacles within 5 evenly distributed quadrats on the horizontal and vertical rock.	

Controlled variables	Within a quadrat, only the 20 largest barnacles were measured.	Because of time restrictions, I could not measure all the barnacles within a quadrat. By measuring only the largest I could discover how large the barnacles of that area tended to grow.
	If a barnacle had an oval shape, measurements were made across where the diameter was the largest.	Ensured that the barnacles were all measured in the same manner.
	The measurements were made on two sides of a single stone	Most of the abiotic and biotic factors experienced by the barnacles were therefore similar. This allowed for an investigation in how only a few factors influence barnacle growth.

II. Procedure

Equipment

- Computer or phone with excel
- $10cm \times 10cm$ grid
- Digital caliper (Whitworth 0-150mm Metr-Iso Electronic)

Method

1. It was noted at what times the tide was low (in this case 7:30 am and 7:30 pm).
2. All the equipment needed was brought to the shoreline at the times of low tide.
3. A rock was identified which had:
    - A large percentage coverage of barnacles
    - One distinct horizontal and one distinct vertical side

4. 5 different sections were decided both on the horizontal and vertical surfaces. The sections were decided based on that they were accessible and that there was a significant percentage coverage of barnacles.
5. The $10cm \times 10cm$grid was placed on one of the decided sections (as can be seen in **Figure 4**)
6. The percentage coverage was calculated by counting the number of squares within the grid without barnacles and subtracting the number from 100
7. The digital caliper was calibrated
8. Using eyesight, an estimation was made of which of the barnacles within the grid were the largest
9. The grid was removed and the 20 estimated largest barnacles were measured with a digital caliper (**Figure 5** and **Figure 6**). If any barnacle had an oval shape, it was measured along the longest side.
10. The results were recorded in an excel table and photos were taken with a phone
11. The grid was then placed on another of the decided sections and steps 5-10 were repeated until all ten sections were investigated.
12. Later, another classmate was asked to measure the length of three separate pebbles with the size of a barnacle with a digital caliper. Upon seeing the difference in results between when they measured and I measured, I calculated the uncertainty.

Figure 3: *The horizontal side of the rock on which Semibalanus balanoides were measured* (Photo by author, 2021)

Figure 4: *Quadrat placed on an area covered with barnacles* (Photo by author, 2021)

Figure 5: *The size of a barnacle being measured with a digital caliper* (Photo by author, 2021)

Figure 6: *The size of another barnacle being measured with a digital caliper* (Photo by author, 2021)

Special Considerations

Safety Considerations: As the shoreline was slippery and full of sharp rocks, students were never there alone and took care in case of injuries.

Environmental Considerations: As there were a variety of organisms living in the intertidal zone (suck as barnacles and anemones), extra care was taken during the investigation to avoid damaging the organisms.

III. Results

Qualitative data

Before taking any measurements, it was noted that there seemed to be a larger density of barnacles on the horizontal part of the rock. Other than that there was no significant qualitative data.

Quantitative raw data

Table 1: Showing the size of the estimated 20 largest barnacles in 5 separate quadrats on the horizontal side of the rock. Also showing the average size and standard deviation of said barnacles. Note: Uncertainty (+/- 0.07) was established by measuring certain objects several times by two different people. The largest difference between the measurements was calculated and divided by two.

	Quadrat 1	**Quadrat 2**	**Quadrat 3**	**Quadrat 4**	**Quadrat 5**
Diameter of 20 largest barnacles (mm +/- 0.01)	12.06	14.81	11.28	10.80	12.20
	14.25	11.48	11.66	10.79	10.58
	11.83	13.27	11.13	12.68	15.46
	11.49	13.03	10.66	14.75	13.42
	11.29	12.33	11.19	12.48	11.98
	11.71	10.68	10.53	13.66	9.79
	10.74	13.07	10.07	12.87	14.87
	10.91	13.96	9.97	18.67	10.03
	10.65	13.10	12.66	13.81	10.68
	11.34	13.01	12.64	10.52	11.16
	11.05	9.66	10.92	11.65	11.80
	13.61	9.44	14.40	13.02	11.13
	11.32	12.43	12.54	13.68	10.88
	9.22	11.57	12.51	12.30	13.24
	9.26	11.53	11.49	11.37	10.92
	9.37	11.13	11.95	11.46	10.13
	11.10	9.87	11.20	11.38	11.93
	8.95	10.41	12.97	13.07	11.35
	9.50	10.79	12.78	12.94	10.12
	9.53	11.01	10.87	10.90	10.84
	9.04	9.45	10.08	10.40	10.05
Average	10.87	11.72	11.60	12.53	11.55
Standard Deviation	1.44	1.54	1.14	1.87	1.56

Table 2: Showing the size of the estimated 20 largest barnacles in 5 separate quadrats on the vertical side of the rock. Also showing the average size and standard deviation of said barnacles. Note: Uncertainty (+/- 0.07) was established by measuring certain objects several times by two different people. The largest difference between the measurements was calculated and divided by two.

	Quadrat 1	Quadrat 2	Quadrat 3	Quadrat 4	Quadrat 5
Diameter of 20 largest barnacles (mm +/- 0.01)	11.46	11.12	9.65	7.74	8.80
	12.44	9.01	9.57	9.07	8.20
	12.24	11.01	8.90	7.52	11.38
	10.32	9.42	10.22	8.61	11.65
	9.48	9.21	9.89	7.32	8.58
	11.01	8.80	9.89	9.27	9.87
	9.83	10.23	11.58	8.22	9.40
	11.07	10.82	9.29	7.43	8.89
	9.38	10.29	9.99	7.38	9.89
	10.52	8.22	9.46	9.10	12.08
	9.92	9.32	9.49	7.76	8.37
	8.81	8.39	10.40	7.80	8.32
	8.84	8.57	9.23	7.51	10.68
	8.36	9.20	10.37	8.14	10.12
	10.63	8.21	9.31	8.00	8.66
	8.38	7.37	8.83	7.47	7.93
	11.17	7.56	9.65	8.67	7.87
	8.06	8.61	10.25	7.89	8.78
	10.42	8.60	9.64	7.45	8.23
	9.10	7.33	9.61	8.02	9.42
	8.91	7.05	9.69	7.55	7.73
Average	10.02	8.97	9.76	8.00	9.28
Standard Deviation	1.27	1.20	0.60	0.61	1.29

Table 3: Showing the percentage coverage in 5 different quadrats on the approximate horizontal and vertical surfaces of the rock, as well as the average and standard deviation

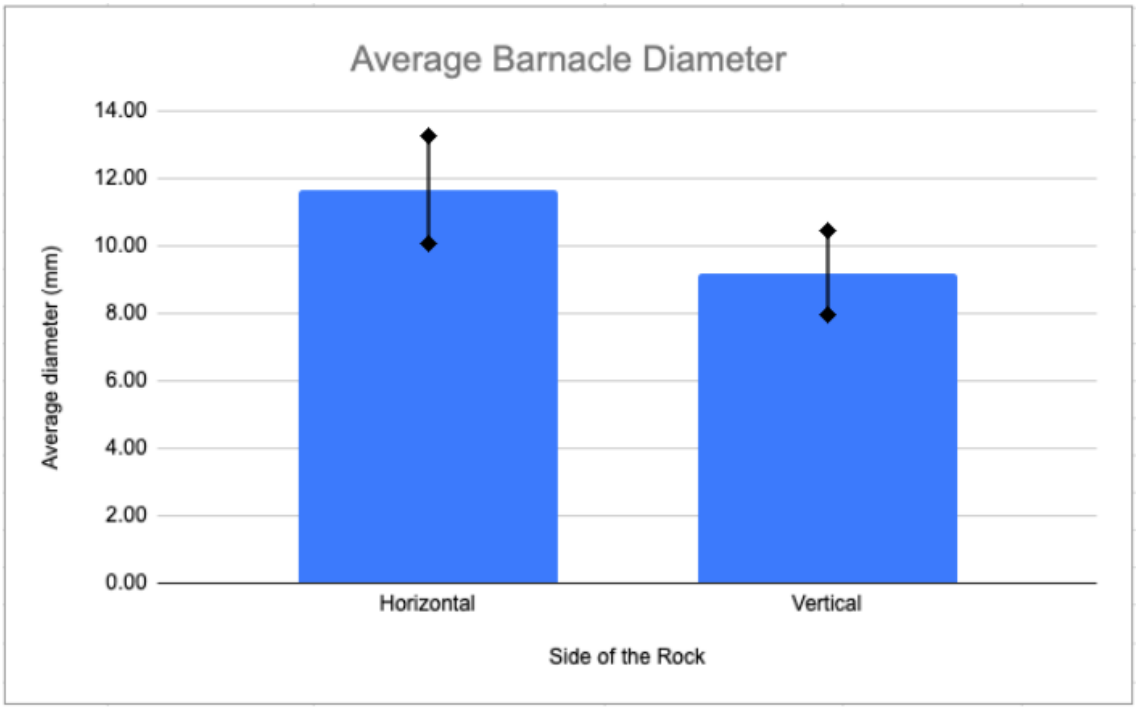
	Quadrat 1	Quadrat 2	Quadrat 3	Quadrat 4	Quadrat 5	Average	Standard deviation
Horizontal surface	91	97	97	89	99	94.6	4.3
Vertical surface	88	81	94	76	75	82.8	8.1

Processed data

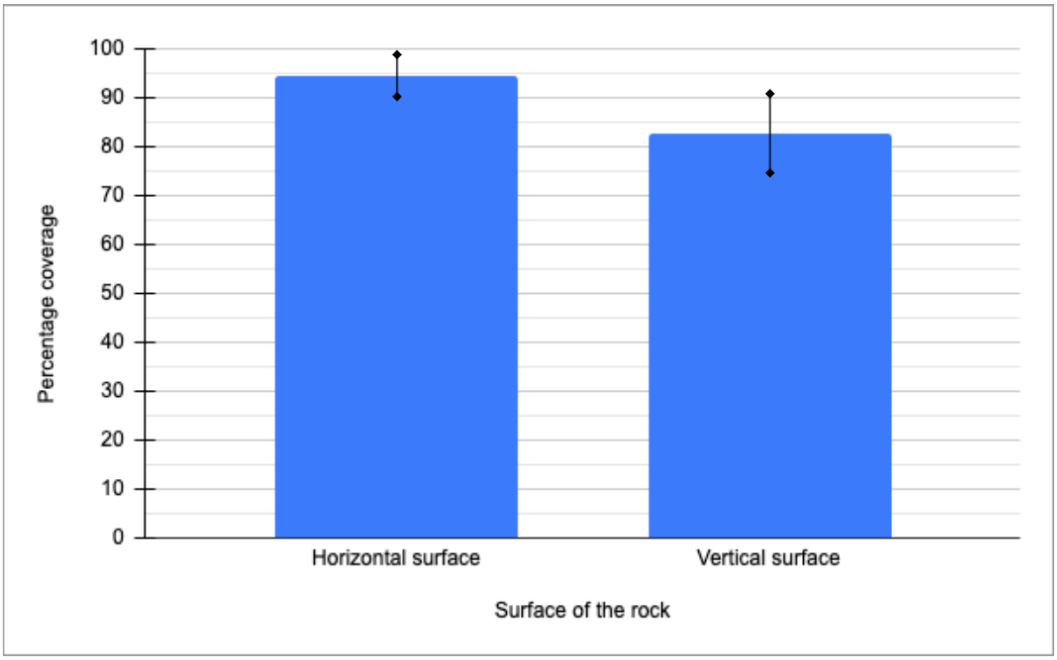
Table 4: The average size (mm) and standard deviation of all measured barnacles on the horizontal and vertical surfaces of the rock.

Side of the Rock	Average diameter (mm)	Standard deviation
Horizontal	11.65	1.59
Vertical	9.20	1.24

Graph 1: Showing the average diameter (mm) of *Semibalanus balanoides* on the horizontal and vertical surfaces of the rock, with standard deviation as black error bars.



Graph 2: Showing the average percentage coverage of *Semibalanus balanoides* in 5 different quadrats on the vertical and horizontal surfaces of the rock, with the standard deviation as error bars.



IV. Discussion

Interpretation

The results show that the largest barnacles on the horizontal side of the rock had an average diameter of 11.65mm, while those on the vertical side of the rock had an average diameter of 9.20mm. This goes to show that the barnacles situated on the horizontal side of the rock generally grew to a larger size. Using excel, the p-value was found to be close to zero (6.8×10^{-27}). As this seemed too good to be true, the t-value was then calculated both by hand and by an online generator but was still found to be as large as 12.45, which led to a p-value of < 0.001, confirming that the results of this experiment were highly significant. The percentage coverage of barnacles was also investigated and was shown to be higher on the rock's horizontal side ($M = 94.6\%$, $SD = 4.3$) than on the rock's vertical side ($M = 82.8\%$, $SD = 8.1$). Performing a t-test with excel showed that the p-value was 0.02. In both graphs, the error bars have a relatively minor overlap and the difference between the two bars is evident. Based on this and the p-values, the data can be acknowledged as significant.

Evaluation

The findings from this experiment support my hypothesis that too high a wave impact will have a negative effect on the growth and distribution of *Semibalanus balanoides*. Research shows that there are many factors influencing the growth and size of the *Semibalanus balanoides*, some of them being barnacle density, water salinity and temperature, seaweed canopies, plankton abundance, time of submersion, sun and wave exposure (Scrosati & Ellrich, 2019; Beerman et al., 2013; Jeffery & Underwood, 2000; Wethey, 1984; Marchinko & Richard, 2003; Scrosati, 2019). Seeing as I investigated barnacles on two sides of the same rock, factors such as water salinity and temperature, seaweed canopy, and plankton abundance would be nearly the exact same and were therefore not taken into consideration for this investigation. More important were factors such as time of immersion, sun, and wave exposure. Of these, wave exposure and velocity seemed to be the greatest differencing factor experienced by the barnacles on the horizontal as opposed to the vertical rock surface.

Barnacles are known to adapt depending on the water velocity and wave impact (Marchinko & Richard, 2003). Those in areas exposed to high water velocity tend to have shorter and stouter cirri, as they need to be able to withstand strong currents. Barnacles in less exposed areas have longer and thinner cirri. In these areas, the low flow of water means that the barnacles spend extra energy sweeping the water for food, rather than in the more exposed areas where energy is used to keep the cirri standing. The metabolic cost of keeping the cirri moving is high enough that the barnacles situated in less wave-exposed areas tend to have lower rates of growth (Marchinko & Richard, 2003). In addition, barnacles submerged for more hours of the day are also recorded to have higher growth rates (Jeffery, & Underwood, 2000). Applying this information to my investigation, it would be reasonable to assume that the barnacles growing on the vertical side of the rock would be of a bigger size. This being both because these barnacles experienced higher water velocity, but also because they were submerged for a little while longer each day than the barnacles situated on the horizontal side of the rock. However, the data in this investigation shows that the barnacles on the vertical surface, the ones experiencing the highest wave velocity, had lower density and were of a smaller size. It is likely that this was because the strength of the waves constantly slamming into the rock wall was large enough to have a negative effect on the growth of barnacles present. The barnacles would experience a constant, heavy and damaging strain from the water. The strength of the waves experienced by the barnacles on the horizontal surface

would not be as large, hence not having as destructive of an effect on their growth. However, they would still experience a high enough water velocity to be growing shorter and stouter cirri, thereby saving energy. The data from this experiment shows how barnacles need a balanced amount of water flow and wave impact to thrive. They need enough wave impact to avoid sweeping the waters for nutrition in order to save energy, yet too much will be damaging.

Sources of Error and Suggestions for improvement

There were several sources of error in this experiment.

Firstly, as I was working it is likely that there was an unconscious bias, both when picking the areas to measure and when looking for and estimating the 20 largest barnacles. Human bias is a source of error that is difficult to avoid but to decrease it I might have asked another person to come with me and help with the estimation and investigation.

Secondly, there should have been a more thorough planning in place when deciding on which 5 sections to investigate on the vertical side of the rock. Instead of placing the quadrats spread out, they should have been placed along a single horizontal line. This way all the samples would have been submerged the same amount of hours every day, and this would have been a control variable which may have led to less variety within the results.

Thirdly, I only measured along the longest possible diameter of a barnacle. This might have affected the results especially because a higher density of barnacles leads to more elongated, narrower shells (Marchinko & Richard, 2003). Since the barnacle density was higher on the horizontal surface, this may have led to the results seeming more significant than they were. These barnacles may not have had a much larger mass, but still a longer diameter due to their elongated shape. The crowded barnacle population also made it difficult to see where one barnacle ended and the other started, likely resulting in inaccurate measurements. To achieve a more accurate idea of the size of a barnacle I could have measured along both the longest and shortest sides and averaged the two numbers. However, this would have led to data from fewer barnacles as measurements in this manner would have taken more time and the water levels were only low enough for an hour or two each time.

Conclusion

The data achieved in this experiment showed that on the stone investigated, the *Semibalanus balanoides* growing on the horizontal surface were larger than those growing on the vertical surface, as they had a mean of 11.65mm while those on the vertical surface had a mean of 9.20mm. The horizontal surface also had a higher percentage coverage. This demonstrates how a high wave impact can have a negative effect on barnacle growth and distribution.

Further investigation

If this topic was to be explored further it would be interesting to attempt to investigate what the ideal wave impact and velocity for *Semibalanus balanoides* is. This would be a long-term investigation which would include finding out how high of a water velocity the barnacles need to experience in order to grow shorter and stouter cirri and avoid sweeping the water for food. Yet the velocity would need to be low enough that the constant water impact would not harm the barnacles.

Sources

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