Length of pelvetia canaliculata on upper shore zone

ABSTRACT:

The aim of this study was to compare the length of Pelvetia canaliculata on the upper shore zone of both wave-sheltered and wave-exposed shores. The hypothesis was that the Pelvetia fronds growing on the upper shore zone of a wave-sheltered rocky shore will be significantly longer compared with fronds growing on the upper shore zone of a wave-exposed rocky shore.

The lengths of 450 fronds in total were sampled using systematic continuous horizontal belt transect sampling method at a wave- exposed and wave-sheltered shores on the Pembrokeshire coast. The results showed that there was a significant difference in the lengths of the seaweed with longer fronds being found in the wave-sheltered rocky shore. This is happening because there is less wave exposure and so fronds are less likely to be broken off at the tips and hence they will be longer.

INTRODUCTION

Rocky shores are areas of bedrock exposed between the extreme high and extreme low tide levels on the seashore. The ecosystem is complex, as it is an interaction between terrestrial and aquatic systems. Plants and animals are distributed on the shore in horizontal zones that relate to the tolerance of the species to either exposure to air or submergence in water during the tidal cycle. This zonation can be very clear and abrupt. Using this fact, I have clearly identified the area Pelvetia canaliculata is found; the upper shore. [1] I have researched this zone in more depth to be able to understand the conditions, the problems and the different variables that can affect Pelvetia canaliculata and the adaptations it developed to survive and thrive.

As the tide level drops on the upper shore, the seaweed will be exposed to air and desiccation (drying out) occurs as a result. Because the tide rises up and down twice a day organisms at the top of the shore get much less water than ones at the bottom. Across a year, the top of the upper zone gets covered by the sea for less than 1% of the year while The bottom of it for about 20% of the year. This is very short time to obtain nutrients from the water for photosynthesis, and can therefore slow growth rate. However, this is not the only problem as the water filters off some of the wavelengths of light and reduce its intensity and so lowering photosynthesis rate. In addition, the water is the main medium where dispersal of spores happens; spending less time in the water means low productivity. [2]

Species on the Upper shore get subjected to a wide variation in temperature. Immersion in water buffers against temperature change due to the high specific heat capacity of water. Upper shore species will have to tolerate the greatest variation in temperature whilst it has least effect in the lower shore. High temperatures will increase the risk of desiccation and increases salinity in pools. [3]

The other major physical factor that controls what can live on a shore is wave action. Exposed shores have a lot of wave action and sheltered shores have little. Seaweeds find the drier, brighter, wave exposed environment very difficult to cope with.

Sheltered shores [4]

Exposed shores [4]

“ Usually face away from the open sea and the prevailing wind. This means they generally have smaller waves than exposed shores which face out into the open sea and the prevailing wind.

Sheltered shores are usually on north to north easterly facing shores. North facing sheltered shores get less sunlight than exposed ones, and are less susceptible to desiccation and in general are more hospitable places for inter-tidal organisms.”

“ Usually face into the open sea and the prevailing wind. This means they generally have bigger waves than sheltered shores.

Exposed shores are usually on south to south westerly facing shores. South to south westerly facing exposed shores get more sunlight than sheltered ones, are more susceptible to desiccation and in general are not hospitable places for most inter-tidal organisms.”

Now that I explained the features of the upper shore zone and the exposed and sheltered shores I will describe the features and the different adaptations that enabled Pelvetia canaliculata to live in such a habitat and constantly changing environment.

Taxon

English equivalent or translation [3]

Phylum

Chromophycota /Brown seaweeds e. g. kelps & wracks

Class

Phaeophyceae /Brown seaweeds e. g. kelps & wracks

Order

Fucales/ Fucoids e. g. wracks

Family

Fucaceae

Genus

Pelvetia

Species

canaliculata

Pelvetia canaliculata is dark olive green in colour, becoming black and brittle as the fronds dry out. P. canaliculata lives for about 4 years and grows up to 150 mm long [3]. The fronds are curled longitudinally forming channels that are dichotomously branched ending in swollen and granular reproductive bodies. They don’t have air bladders or mid-ribs.

Pelvetia canaliculata [3]Pelvetia canaliculata grows attached to hard substrata using their holdfast; this has the mechanical features of a root system that would be beneficial for the seaweed, holding them steady no matter how turbulent the water movement. It tolerates ultra sheltered to moderately exposed conditions. The algae P. canaliculata is limited from living higher on the shore by desiccation, but is prevented from colonizing lower levels by competition from other species of algae. Seaweeds also have to cope with grazing pressure from mobile gastropods. [5]

Over the period of neap tides, the plants may lose up to 65 per cent of their contained water and become dry and blackened. But when the spring tides extend over them, water is absorbed and the normal olive-green colour and softer texture are regained. It has been estimated that the upper shore plants are exposed for 90% of the year. [6] In water, seaweed obtain the carbon they need for photosynthesis from dissolved co2 or bicarbonate (HCO3-). When exposed to air, photosynthesis can only take place with uptake of CO2 from air. As long as the seaweeds do not dry out, many species photosynthesize in air at rates similar to those measured when they are fully submerged. However, as they begin to dry out, their ability to photosynthesize diminishes. Pelvetia canaliculata is found high on the shores and is prone to drying out for long periods of time. The species can photosynthesise when exposed to air but may suffer nutrient stress as it can only obtain nutrients when submerged. Researchers found that within less than a day of being back in seawater, as specimen that had been desiccated for 6 days was able to resume full rates of photosynthesis. In fact P. Canaliculata requires periods of exposure to the air. If it is submerged for more than 6 hours out of 12 it actually starts to decay. This is a rare example of a seaweed species in which periods out of water are absolutely essential. [7]

An increase in wave exposure and water flow rate may cause Pelvetia canaliculata to be torn off the substratum or the substratum with plants attached may be mobilised. It is unlikely that any Pelvetia canaliculata will live in areas of very high wave exposure. In faster moving water the risk of the fronds tearing will increase because of the increased drag. Hence Pelvetia canaliculata adapts its shape to reduce drag depending on their location. Pelvetia fronds growing on wave-exposed shores are shorter and thinner because the fronds are frequently broken off at the tip.

Pelvetia canaliculata has many adaptations that allow it to survive better in the upper shore compared to algae living down. They have; rolled fronds to reduce water loss in evaporation, channels to trap water in the frond, a fatty (oily) layer over the cell that stops water evaporating to slow desiccation, a thick cell wall which shrinks with drying, the ability to survive low nutrient level, a rapid recovery of metabolism when the tide returns during respiration and photosynthesis. “ It is therefore, a very stress-tolerant alga, well adapted to the niche at the top of the shore. ” [2]

Based on the information I researched in the introduction I will investigate and compare the adaptations of Pelvetia canaliculata on two different sites where the conditions are different. I will compare the lengths of the fronds of Pelvetia canaliculata on a wave-sheltered rocky shore and a wave-exposed rocky shore.

EXPERIMENTAL HYPOTHESIS: There will be a statistically significant difference between the length of the Pelvetia canaliculata growing on the upper shore zone of both a wave-exposed and a wave-sheltered rocky shore; and that its fronds are going to be on average longer in the wave-sheltered shore compared with the wave-exposed rocky shore as there is less wave exposure and so fronds are less likely to be broken off at the tips and hence they will be longer.

NULL HYPOTHESIS: There will be no statistically significant difference between the length of the Pelvetia canaliculata growing on the upper shore zone of both a wave-sheltered and wave-exposed rocky shores . Any difference however, will be due to chance factors.

VARIABLES:

The table below lists and briefly explains the variables that could affect the reliability of the investigation and how they will be controlled.

Exposure (independent)

An exposed shore means larger fetch hence greater wave action which leads to the damage of the Pelvetia canaliculata fronds

I will be carrying out the investigation in areas classified by the Ballantine's biologically defined exposure scale to be wave-sheltered and wave-exposed.

For the wave-sheltered shore I will collect my data at Angle Point site, SM 875 033 which is a wave sheltered rocky shore inside the Milford Haven estuary, Angle Point is 12km north-west of Pembroke. Facing north-east, the shore is sheltered from the prevailing south-westerly winds and has a small fetch. The Ballantine's biologically defined exposure scale classifies this site as Grade7- very sheltered.

For the wave-exposed shore I will collect my data at West Angle Bay, SM 852 032 which is a wave exposed rocky shore on the Atlantic coast of

Pembrokeshire and lies 14km north-west of Pembroke. Facing south the shore has a large fetch (to south America). The Ballantine’s biologically defined exposure scale classifies this site as Grade3- exposed.

Length of Pelvetia canaliculata (dependent)

There are some variables that would affect the growth rate of the fronds and therefore its length. Some of these variables include The height on shore, wave action, and the abiotic and biotic factors. All the effects of these variables are explained below.

I will be measuring all my samples on both shores in mm using the same 30 cm ruler.

The height on shore

From my research I know that Pelvetia canaliculata only colonises the upper shore zone.

However, the abiotic factors will affect the different zones on the upper shore differently for example the effect of wave action on the lower part of the upper shore zone is different than that on the higher part of the upper shore zone. Also the water coverage in the lower part of the upper shore is 19% more than the higher part. Hence, there will be more nutrition uptake, resulting in different growth rates.

I will be measuring both samples on both shores horizontally across the upper shore zone using horizontal continuous belt transect technique. To ensure that I’m working on the same height I will be using a cross staff.

Wave action

The strong force produced by the powerful wave action will decrease the fronds growth rate. The fronds will adapt by becoming shorter so that the drag force is lessened.

I cannot control any of the abiotic factors but I will measure them to see if they have any affect on the samples I will be measuring on the two different sites.

However, I will take both my samples on the same periods of the day, on the same season and on the same shore area

Humidity

Wind spray increases the humidity, this will be higher on the wave-exposed because of the greater and higher wave action

Light intensity

Needed for photosynthesis. Although the Pelvetia canaliculata requires to be immersed in seawater for this to occur, the process still takes place slowly in air.

Wind speed

Wind increases the rate of transpiration as it moves the layer of water out side the stomata, which contributes towards the desiccation of the fronds.

Rock gradient

The steeper the rock the harder the wave will hit it causing greater damage for the fronds. Also a flatter shore will expose a greater area of substrate for colonizing and will not drain as fast as a steeper slope.

Aspect

It is the direction the rock faces. South facing shores will have more illumination and warmth, but dries faster; north facing shores are cooler, darker and less likely to dry out. Thus, on a north facing slope community bands of Pelvetia canaliculata will be wider and higher up the shore.

Substrate or rock type

The hardness and size of rocks will influence an organism's ability to attach itself. Soft rocks will not be suitable for hold fast to attach on. If stones are too small they will be mobile, moving around in the surf and so prevent any organism from attaching itself to the rock.

The type of rocks on both sites should be the same.

Apparatus and Justification

30 cm ruler

To measure the length of the frond on the Pelvetia canaliculata. From my research I found that the fronds average height is 15 cm, hence I chose 30 cm ruler.

1/4m quadrat

I think that this is a suitable size to measure a sample of small organism, as it will include an appropriate number of Pelvetia bunches. The quadrat will be used to carry out the continuous horizontal belt transect.

0. 6m Cross staff

To make sure that all the data collected on both sites are gathered at the same height, so ensuring a fair test.

Pencil

To record the data with. Its useful incase it rains, my data will be safe and the values will not get lost

Calculator

To keep calculating the running mean

Water proofs

For safety reasons and for protection from wind chill and spray. The Wellingtons boots to avoid slipping and falling.

Gloves

To protect hands from the mucus layer on the Pelvetia canaliculata

To calculate the height of the data collecting area the time of the low tide and its height is needed: On Monday 25/09/06 the low tide is 1. 1m at 14: 42; and on Tuesday 26/09/06 the low tide is 1. 28m at 15: 10.

ETHICAL CONSIDERSTION:

Consideration has to be given to the organisms living on the shore; so the seaweed will be measured where it lies without cutting or destroying the living specimens. Care will also be taken to move around the shore without stepping on delicate sea life such as snails and crabs. Also if any animals living on the seaweed like snails are removed so that the seaweed could be measured ensure that they are released close to their point of capture and in a manner that will give them a good chance of survival. Finally ensure that you know the local regulations concerning the protection of habitats and endangered species and always obtain the consent of licensing authorities, landowners, etc.

PRELIMINARY INVESTIGATION:

Preliminary work was done as a group to learn about the different shore zones as well as the different species that are found in each zone and the adaptation they developed to survive at extreme conditions like desiccation for instance.

Also before carrying out the full investigation a pilot study was conducted on any random 10 Pelvetia bunches to find out the best way to measure their length and to determine which branch of the frond to use when measuring.

From the preliminary investigation I found out that I would be measuring the longest branch of the longest frond of each pelvetia bunch. I will also be placing the end of the ruler on the ground where the Pelvetia’s hold fast is found. Finally, I’ll also make sure to keep it vertical all time to ensure a fair test.

[Figure 3] First of all, check the time of the day when the low tide occurs and its height above chart datum. The help of a friend who has the same height as you is needed for this part in the method. At the time of the low tide, stand at the lowest part of the lower shore where the tide is at its lowest and place the cross staff on the ground in a way that you are facing one of its sides and the other side is facing the upper shore direction where the Pelvetia canaliculata grow (data collecting area) [figure 1]. Lower your body so that your eyes are level with the opening in the cross staff. On the mirror observe the reflection of the small tube that is filled with coloured liquid which contains a small bubble and two marked lines in the middle of the tube. [Figure 2] Supporting the body of the cross staff with one hand and moving the flexible plastic part up and down, adjust the position of the bubble so it stays still between the two marked lines on the tube. Instruct and direct your friend to move around until you can see her/his boot through the opening in the cross staff. Ensure that she/he does not walk backwards as the shore is very slippery because of the mucus on the algae and the small pebbles and rocks makes it very easy to fall down. When you are able to see the boot, ask your friend to stop and not move from that point. Now stand up and walk up to your friend with your cross staff. Place the cross staff on their boot position, after she/he move their boot. This is the new spot. Repeat the above procedure until you reach the upper part of the upper shore where Pelvetia canaliculata grows (data collecting area). [Figure 3] Every time you move up with the cross staff to a new spot, you are gaining 0. 6 m in height. Keep recording and adding the height gain every time you changed to a new spot. At the end add the total height gain in meters to the height of the low tide; the result will be the height of the data collecting area.

When you reach the upper shore where the Pelvetia canaliculata is, place the 1/4m quadrat on the first area where they are seen. To avoid bias start measuring to the nearest mm the length of the longest frond of each bunch found within the whole quadrat starting from the right hand side and then moving across to avoid measuring the same bunch more than once. [Figure 4] The Pelvetia canaliculata fronds grow in bunches where each bunch is attached by one holdfast to a rock. The fronds lay on top of each other in the sea direction. So when you start measuring, position yourself on the opposite direction to the Pelvetia's. [Figure 5] After putting your gloves on, start by gently gathering a bunch of Pelvetia canaliculata up right; make sure that all the fronds in this bunch spring from the same hold fast. Also as a control make sure that the bunch is attached to a substrate and not in a rock pool. Keep your face at distance as there will be small flying organisms and always try to minimise the disturbance to other organisms that live there as much as possible. Now slide the hand that is holding the Pelvetia bunch up, so that all the fronds are laid up against each other. [Figure 6] Now it is easy to determine the longest frond; with the free hand, hold the tip of the longest frond and leave the rest of the fronds to fall down towards you or in the opposite direction of the sea, so that you do not measure this bunch again. Still holding up the longest frond, line up the 30 cm ruler against the frond with the free hand. Make sure that the ruler is parallel to the frond with the 0 mm edge resting flat on the rock to ensure correct and accurate measurement. [Figure 7] The ruler used should be plastic with a smooth base and not metal so it does not cut through the fragile fronds or get rusty, it is also easier to read off measurements as it is see through. Now read the length of the frond and record it to the nearest mm in the prepared recording table. Place the results and the calculator inside a plastic bag incase of a bad weather. Place the frond with the rest of the bunch in your direction

Do not include pieces of debris, or any seaweed merely unattached to a rock in the investigation as this will lead to misleading results. Also do not measure dead fronds as they will cause anomalies in your data. These fronds are usually desiccated and very brittle; their colour is black instead of the olive green. Ask a teacher or an expert to confirm.

Measure all the Pelvetia canaliculata on the sides of the rocks and all the ones that have their hold fast within the quadrat even if all or some of the fronds are outside, as the quadrat frame is relatively thick so it might cover some of the Pelvetia canaliculata fronds. Rock pools provide artificial environments, and so do not included these areas in the investigation. After you finish measuring all the Pelvetia bunches within the first quadrat, flip it to start on a new one. This is systematic continuous horizontal belt transect sampling. When flipping the quadrat use your hand to secure the right/left hand side of the frame-depending on where more of the Pelvetia is found- and then flip the left hand side of it so it becomes the right hand side now. [Figure 8] Every time you record 5 new measurements, calculate the running mean to see if the sample size is large enough. When you get at least three consecutive running mean values which are the same to 2 decimal places, calculate ± 2. 5% value of the repeated value and then double the sample number. If the running mean continues within the range until the last required sample then stop. However, if it goes outside the confidence limits calculate a new range.

Abiotic factors method:

Wind speed measured using an anemometer: Hold it facing the wind. Wait for 20 seconds until the reading stabilises. Record the average measurement in m/sec.

Humidity measured using a whirling hygrometer: whirl the hygrometer for 20 seconds. Record the temperature of both the wet and dry thermometer. Use the chart to work out the humidity percentage.

Temperature measured using a thermometer: record the temperature of the dry thermometer when using the whirling hygrometer.

The statistical test

I will be using the z-test to test for statistically significant difference between the sample mean and the population mean for both the wave-sheltered and wave-exposed sets of data. The reason this test is used and not the t-test is because my sample exceeded 30 data points.

Z= (S1)2 + (S2)2

a) Square both standard deviation

Wave-Sheltered

Wave-exposed

24. 48^2 = 599. 2704

14. 99^2 = 224. 7001

b) Divide each answer by n= 225

599. 2704 ÷ 225

= 2. 66342

224. 7001 ÷ 225

= 0. 998667111

c) add both values obtained from step (b)

2. 66342 + 0. 998667111

= 3. 662091111

d) square root result obtained from step (c)

âˆš 3. 662091111

= 1. 91365909

e) | Ð¥1 – Ð¥2|

Mean of site 1 – mean of site 2

104. 06 – 35. 71

= 68. 35

f) divide result obtained from step (e) by result obtained from step (d)

68. 35 ÷ 1. 91365909

z= 35. 72

z= 35. 72

When Degrees of freedom = âˆž:

Level of significance P= 0. 05, the Critical value = 1. 960

Z > critical value

35. 72> 1. 960

The reason p= 0. 05 was used is because it is the standard level of significance used to justify a claim of a statistically significant effect. In the curve of normal distribution of a normal population Alpha level is 95% and this is normal, outside of that is 1-alpha or 5%. This 5% (0. 05) means, that normal falls within this range, beyond that, would be too rare to be by chance alone and must be by the effect of something wave action for example. A p value <0. 05 means that there is " statistically significant" difference from one population to the other.

As my results were significant at p <0. 05, I wanted to see if they were even more significant at the p < 0. 01 level.

Level of significance P= 0. 01, the Critical value = 2. 576

Z > critical value

35. 72> 2. 576

The z value obtained is significantly greater than the critical value at the p < 0. 01 significance level. This shows that there is a statistically significant difference, hence I will accept the experimental hypothesis and reject the null hypothesis.

Graphs are presented in the next couple of pages.

ANALYSIS AND CONCLUSION:

The results tables and the graph comparing the mean length of Pelvetia canaliculata between the wave-sheltered and the wave-exposed shores clearly display evidence supporting the hypothesis. Looking at the mean graph I could evidently see that the sheltered shore has a higher mean than the exposed shore; more than 2. 9 times higher to be exact. This is because in faster moving, turbulent water and strong wave action like in the wave-exposed shore, the risk of tearing fronds is increased due to the increase in dragging force. Pelvetia canaliculata adapt its shape to reduce drag depending on its location. Fronds found at wave exposed shores are shorter and narrower as they are frequently broken off at the tips.

The error bars for both shores are fairly large which indicates that there is quite a lot of variation in the results and so reduces the reliability of the data. Similarly the difference between the standard deviation of both sets of data is rather large, with 24. 48mm for the sheltered shore and 14. 99mm for the exposed shore. Even though this shows a great range in my data hence more variability and less reliability, still as it applies to both data sets, making comparisons should be safe.

The frequency histograms for both shores shows that the data collected at the wave-sheltered site is more varied than the exposed site as it is spread over 13 categories as opposed to only 9 for the exposed shore. The frequency histogram for the sheltered shore shows a bell curve pattern, displaying a normal distribution with the peak at the 80. 00-89. 99mm category. On the other hand the wave-exposed histogram displays a positive skew as most of the data is lying to the right hand side with the most common length of Pelvetia is within the classes 20. 00-29. 99mm. The skew could have occurred because I found great difficulty measuring the very small frond of Pelvetia growing on the wave-exposed shore, and so not including them in the results. Also an increase in water flow rate cause plants to be torn off the substratum or the substratum with the plants attached may be mobilised and so washing away the young Pelvetia plants. Pelvetia canaliculata is permanently attached to the substratum so once removed it cannot re-form an attachment. I think that these factors together helped create this gap in the histogram.

The peaks of both histograms are very far apart. This shows that there is a significant difference between the lengths of Pelvetia canaliculata on both sites. This has even been proven further by the Î–test, which showed 99% significance. However, there is quite an overlap between the two curves. This overlap is between 40. 00-99. 99 mm categories. This overlap could be explained by the similarity in the abiotic factors between the two sites. Also the exposed shore received more sunlight than the sheltered one, which was shaded by a cliff; this means that the Pelvetia canaliculata on the exposed shore were able to photosynthesis more. These factors could have enabled some fronds to have a faster growth rate than others and so became longer. Or it could be that on the exposed shore the wave action is greater and so spray will splash higher up the beach than on a sheltered shore with fewer waves and so this will provide more nutrients for the fronds to grow longer during some exposed periods.

Although a bell curve pattern is recognised on the wave-sheltered site there are three identified anomalies. Firstly, the frequency of the histogram at category 90. 00-99. 99 mm would be expected to be lower than that of category 100. 00-109. 99 mm but at the same time higher than the frequency of 80. 00-89. 99 mm. One explanation for this anomaly could be due to smothering. If smothering took place when the plant was emersed the whole of the plant would be buried under the sediment preventing photosynthesis that is taking place very slowly in the first place. If smothering however happened while the plant was immersed, some of the fronds may escape smothering and be able to continue photosynthesis. This will still lower the growth rate and so fronds' length.

Another explanation is that within the same quadrat I measured the Pelvetia canaliculata that grew on both sides of the rock. It is expected that the length of the Pelvetia fronds growing on the side of the rock facing the direct wave's action to be shorter than the other landward facing side. This is because the initial force exerted by the wave will be absorbed by the Pelvetia fronds growing on the sea-facing side of the rock; this will cause the fronds to be frequently broken off at the tips and so will make them shorter. On the other hand, the sheltered side of the rock is only getting wave force that has been weakened by the seaward facing side of the rock and so the fronds length will not be affected as much. To control this in future I will restrict myself to measuring the length of the Pelvetia fronds on only one side of the rock(sea/landward facing) to get fairer results.

Another reason to explain the anomalies displayed on the histogram could be that the swollen reproductive fruiting bodies on some of the Pelvetia canaliculata added a few mm to the length. On the other hand it could be explained by intraspecific competition. The fronds in the 110. 00-119. 99 mm category could be shading and preventing the sunlight from reaching the fronds in the categories below it as they are longer; this means that less photosynthesis is taking place and hence slow growth rate and shorter fronds, in other words they will be out competed for light.

The two measurements recorded at 160. 00-169. 99 mm could be an exception of over growth or mutation as from research Pelvetia is expected to grow no more than 150mm in length. On the other hand, this anomaly could also indicate that there might have been some errors happening while taking measurements.

Even though I couldn’t measure the sunlight intensity received by the Pelvetia canaliculata on both shores as the equipment required weren’t working, I observed that the wave-exposed shore received more sunlight then the sheltered one. This is because the wave-exposed shore has a southern aspect. However this slight difference in the light intensity received by the chlorophyll on the different shores can affect the growth rate; light is also an important factor in allowing good settlement of spores by stimulating the growth of rhizoids which anchor the young plant to the rock. This is reflected on the data collected from the wave-exposed showing the overlap with the wave-sheltered shore’s data.

The humidity measured on both sites is quite similar with the wave-sheltered shore being very slightly more humid. This difference in humidity was only expected on the wave-exposed shore due to the wave action being greater and so spray will splash higher up adding to the air humidity than on the sheltered shore with much fewer, weaker waves. The explanation that I find convincing and convenient for the increased humidity on the wave-shelt