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THE MORPHOLOGY OF LIMPET SPECIES ON THE ROCKY SHORES OF LUNDY

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ABSTRACT

Lundy has shores of every orientation making an ideal opportunity for research into the ecology of the coastal zone. Here the results of a final year undergraduate research project are described. The dimensions of limpets were measured on six shores around Lundy and the relationship between shell length and height established. The results show that there is a difference in size between limpets present on the upper and lower shore, with larger limpets generally found on the upper shore. Also, shell shape can be correlated to shores of differing wave exposure with more exposed shores possessing smaller and more conical individuals than those found on sheltered shores.

INTRODUCTION

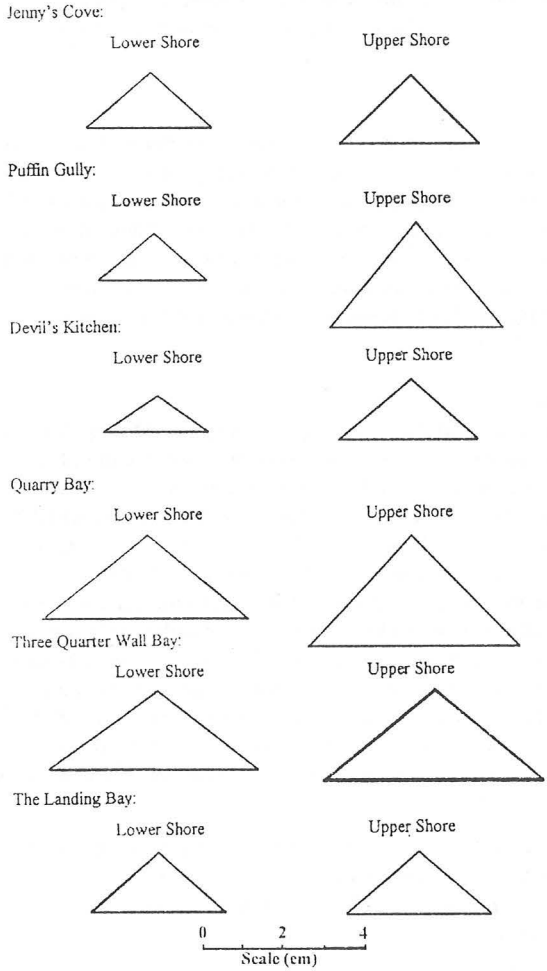
The shores of Lundy are exposed to a range of strengths and frequencies of wave action. This range of wave exposure provides the opportunity to study the morphology of limpets (*Patella* spp.) in relation to the severity and frequency of wave action. There are a number of views concerning the morphology of limpet species and the environmental factors that influence them (Beaumont and Wei 1991; Branch and Marsh 1978; Davies 1969). One belief is that shell shape may be influenced by wave exposure, which apart from size, type and frequency of waves approaching the shore, is determined by environmental conditions such as topography, orientation and gradient of shore (Brehaut 1982). Generally, if the shore is extensive, flattened and irregular, the wave conditions will be gentle, but if the shore is steep and has no shelter, wave action will be violent. Brehaut (1982) states that on wave exposed shores the repeated muscular contraction of the foot, required to maintain the position of the limpet, results in the mantle being drawn inwards. This in turn results in the shell becoming tall and narrow, or more conical. Conversely, on a less exposed, or sheltered shore it would be expected that limpets would be more flattened

This paper reports the findings of a final year undergraduate research project. The aims of this study were to investigate the effects of exposure on the morphological adaptations of limpets and to ascertain whether a relationship exists between shell shape and degree of shore exposure to wave action.

METHOD

Six sites were chosen as a means of assessing the effects of different wave exposures on the morphology of *Patella* spp. (Table 1). The shores were graded subjectively according to aspect, wave action and extensiveness, and assigned a rating between 1 and 5. The exposure

Figure 1. Representative cross section through *Patella* spp. to show the mean length and height for the upper and lower shores for each site. The apex is taken to be central to the limpet shell, which is not entirely accurate but allows for easier comparison.



ratings for Quarry Bay, The Landing Bay and Jenny's Cove correspond to ratings previously allocated by Hawkins and Hiscock (1983).

Although there are three species of *Patella* (*P. vulgata, P. ulyssiponensis* [otherwise referred to as *P. aspera*] and *P. depressa*) found on the rocky shores of the British Isles, individuals were not identified to the species level in this study. This is due to the destructive nature of identification combined with respect for Lundy as a Marine Nature Reserve.

The sample of limpets was chosen using random number tables to determine the starting point of an interrupted belt transect from the upper limit of their distribution to as close to sea level as the author could reach during low tide. The same technique was used to select the subsequent positions of quadrats along the transects. Within each 1 m sq. quadrat one limpet was chosen arbitrarily. From this limpet four further individuals were selected at varying distances, again determined by random number tables. Limpets were measured *in situ*. The greatest length and the greatest width of the shell were measured using calipers. Height of the shell was measured using a sliding rule.

The sample number of limpets varied between sites, owing to time constraints caused by tidal influences at some shores. Study was also restricted to a two week period, which prohibited extensive collection of data. The raw data was then subject to statistical analysis (using Analysis of Variance, t-tests and linear regressions) to establish whether there was a relationship between exposure of a shore and *Patella* morphology. Statistics account for unequal sample sizes.

RESULTS

The length, width and height of limpets (Tables 2a & 2b; Fig. 1) varied between shores and within a single shore. Statistical analysis supports these results by indicating where significant differences lie.

Analysis of Variance shows a highly significant ($p<0.001$) difference for all of the morphology measurements between the lower and upper shores. In other words, there are differences in the length, width and height measurements between the upper shores, and also between the lower shores, which reaches statistical significance. Limpets of different shores are therefore of different sizes, but also of different shapes (eg. conical/flattened).

T tests were used to indicate differences within a single shore. Analysis showed significant differences between the upper and lower extents of each single shore, with the exception of the Landing Bay. Three Quarter Wall Bay and Quarry Bay were statistically shown to have significant differences between the upper and lower shores for height only ($p=0.05$), with no significant difference for length or width. Devil's Kitchen ($p=0.01$), Puffin Gully ($p=0.01$) and Jenny's Cove ($p=0.05$) had significant differences for all measurements taken.

The final analysis of the morphology data involved the use of linear regressions (Table 3) to define the relationship between length and height at the lower and upper shores of each site. The regression determines the gradient, or steepness, of the shell and as such denotes conicalness (with a high gradient) or flatness (with a small gradient). It is necessary to test the significance of the regression in order to illustrate the probability that there is a true linear relationship between length and height.

DISCUSSION

The Analysis of Variance clearly shows that the upper shores of the different sites possess *Patella* individuals of very different dimensions. Significant differences were also shown between the lower shores for each dimension, although the fact that the lower station depended on tidal height makes samples not strictly comparable. It was found that on the exposed shores of the west coast (Devil's Kitchen, Puffin Gully and Jenny's Cove) *Patella* individuals were far smaller in size than those found on the sheltered shores of the east coast. Furthermore, the *Patella* individuals on the Landing Bay shore were also significantly smaller than those on the other two east coast shores (Three Quarter Wall Bay and Quarry Bay). The Landing Bay is a very sheltered shore and its similarity with the truly wave exposed shores negates a relationship between shell size and exposure to wave action. It is possible to speculate that on an exposed shore, only *Patella* individuals that have small shell dimensions are capable of survival; however, there is no such explanation for the small shell dimensions of The Landing Bay.

Within a single shore it has been observed that significant differences in size occur between *Patella* individuals on the upper compared with the lower shore. At the upper shore, for each dimension, limpets are larger (with the exception of the Landing Bay). However, Three Quarter Wall Bay and Quarry Bay had significant differences for height only, indicating that at the upper shore organisms are more conical. Devil's Kitchen, Puffin Gully and Jenny's Cove all had significantly different sizes of limpets at the upper and lower ranges for each dimension.

The difference between shell shape on the upper and lower parts of the shores is most likely due to different periods of emersion. The upper part of the shore could therefore be considered as having harsher conditions leading to greater problems of desiccation, which has also been linked with shell shape of *Patella* spp. (Davies 1969). Other non-favourable conditions, for example chemical factors including lowered salinity during rainfall and oxygen availability, may also require *Patella* spp. to adapt morphologically and behaviourally (Lewis 1964). Lowell (1984) has proposed that predation may influence the shape of limpet shells. The regression analysis used here gives an indication as to how the wave exposure of a shore can also affect this, and it has been proposed (Brehaut, 1982) that the more exposed the shore, the greater the height of a limpet proportional to other measurements. Thus, the greater the gradient of the shell, the more conical the limpet.

The regression analysis of limpets on Lundy showed some correspondence to Brehaut's (1982) theory, particularly on the upper shores of each site where regressions can be ranked in order of limpet shape, from conical to flattened. The expected relationship is clearly shown: that the more exposed a shore to wave action, the greater the steepness of the limpet shell. According to the gradients of the regression equations (shown in Table 3) the upper shore morphologies are placed in the following order:

	Rank according to Shell Morphology (steepness of the shell)	Wave exposure rating
Conical	Puffin Gully	4
	Jenny's Cove	5
	Devil's Kitchen	3

	Three Quarter Wall Bay	2
	The Landing Bay	2
Flattened	Quarry Bay	2

The sequence of the upper shore populations corresponds well to the original grading of the shores according to wave exposure (Table 1). The three wave exposed shores have a more conical limpet shell shape, and the three sheltered shores possess more flattened limpets.

In conclusion, the results show a positive correlation between the conicalness of limpets and exposure of a shore, but this could be due to species dominance. For example, Quarry Bay possessed large limpets compared to those found at Devil's Kitchen. It is possible that on Quarry Bay the dominant species is *P. vulgata* or *P. ulyssiponensis*, both of which grow to up to 60 mm in length. However, *P. depressa* grows to only 30 mm in length (Fish and Fish 1989), which if predominant on Devil's Kitchen may lead to false conclusions about size being related to wave exposure. Also, the sample size was quite small for a statistically based study, but unavoidable owing to time restrictions, and should be increased if this study is repeated. The results are therefore indicative rather than definitive. Although the results appear to reflect conclusions from previous literature (Beaumont and Wei 1991; Brehaut 1982) further research may provide a different explanation for the link between shell shape of *Patella* spp. and shore exposure.

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Table 1. The sites investigated. Each shore was allocated an exposure rating (given in the table), on a subjective scale from 1 to 5 (very sheltered to very exposed), based on extensiveness of shore, wave action and topographic relief.

Location	Grid Reference	Description	Exposure Rating
Jenny's Cove	132459	A steep shore on the west of the island, which is highly susceptible to the force of Atlantic winds, and currents.	5
Puffin Gully	134481	A steep shore on the north of the island.	4
Devil's Kitchen	148437	An extensive shore on the south coast with shallow incline. Sheltered by topographic relief from the south west of the island.	3
Quarry Bay	140448	An east facing shore with protection offered by the headlands enclosing the shore.	2
Three Quarter Wall Bay	139466	Another east facing shore, sheltered by the rock protrusions enclosing the shore.	2
The Landing Bay	145438	A north east facing shore with a high level of topographic relief.	2

Table 2a. The mean measurements for each lower shore studied. Standard deviation from the mean and the number of individuals measured are included.

Site	Height above Chart datum (m)	Variable	Mean (mm)	Standard Deviation	Number Measured
Jenny's Cove	2.3	Length	29.76	6.809	25
		Width	24	5.98	25
		Height	12.36	3.94	25
Puffin Gully	0.5	Length	26.04	10.11	25
		Width	20.88	9.1	25
		Height	9.96	5.103	25
Devil's Kitchen	2.1	Length	26.16	5.41	25
		Width	20.76	5.101	25
		Height	8	2.69	25
Three Quarter Wall Bay	0.3	Length	52.75	8.87	44
		Width	46.8	9.0722	44
		Height	18.5	5.394	44
Quarry Bay	0.3	Length	49.76	7.096	25
		Width	42.08	6.422	25
		Height	20.68	4.12	25

		Length	34.52	8.38 25
The Landing Bay	1.8	Width	28.52	7.55 25
		Height	14.2	4.91 25

Table 2b. The mean measurements for each upper shore studied. Standard deviation from the mean and the number of individuals measured are included.

Site	Variable	Mean (mm)	Standard Deviation	Number Measured
	Length	34.24	7.55	25
Jenny's Cove	Width	27.24	6.82	25
	Height	16.24	5.0	25
	Length	41.36	6.82	25
Puffin Gully	Width	35.76	6.34	25
	Height	23.72	6.11	25
	Length	33.48	6.74	25
Devil's Kitchen	Width	27.08	5.63	25
	Height	14.04	4.54	25
	Length	54.45	8.65	44
Three Quarter	Width	47.68	8.28	44
Wall Bay	Height	21.23	4.997	44
	Length	51.79	5.87	50
Quarry Bay	Width	43.12	6.11	50
	Height	26.54	5.82	50
	Length	36.36	4.61	25
The Landing Bay	Width	30.36	4.27	25
	Height	9.5	2.52	25

Table 3. The results from the regression analysis. A higher gradient (closer to 1) indicates a steeper and more conical limpet shell, with a lower gradient indicating a flattened shell shape. $P<0.05$ indicates a significant regression, a p value of greater than 0.05 is not significant.

Site	Shore	Significance	Gradient (steepness of shell)
Devil's Kitchen	Lower Shore	$p<0.05$	0.442
	Upper Shore	$p<0.05$	0.525

Jenny's Cove	Lower Shore	$p<0.05$	0.478
	Upper Shore	$p<0.05$	0.575
Puffin Gully	Lower Shore	$p<0.05$	0.449
	Upper Shore	$p<0.05$	0.769
The Landing	Lower Shore	0.897	0.461
Bay	Upper Shore	$p<0.05$	0.426
Quarry Bay	Lower Shore	$p<0.05$	0.461
	Upper Shore	$p<0.05$	0.422
Three Quarter	Lower Shore	$p<0.05$	0.521
Wall Bay	Upper Shore	$p<0.05$	0.517