Cirral Length and Wave Exposure in the barnacle, *Semibalanus cariosus*

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Introduction

Barnacles are very prevalent on many coasts throughout the world's oceans. They are suspension feeders that filter food from the water column. They are attached to rocks, wood, or even living organisms in the water. During their larval stage of life, barnacles are mobile and at this stage find a substrate to land on and spend the rest of their adult life on. They attach onto a surface with their heads and cement themselves down and then secrete the shell material to make their calcareous plates that protect their soft bodies. Since they are non-mobile for most of their lives as an adult, barnacles depend on water flow to bring food to them. To collect food from the water, barnacles use their feet (cirri) which are facing upward from their calcareous plates, to bring in particles (Ingram 2007). In order for the cirri to work, barnacles must have some form of water flow.

An example of a large species of barnacle is the thatched barnacle, *Semibalanus cariosus*. The thatched barnacle is found in the mid intertidal to shallow subtidal, many times underneath the thickest band of acorn barnacles in the low intertidal. They range from Alaska to Central California on the West Coast of the United States as well as in some parts of Japan. They are generally found on rocks, floats, or pilings with a high number found on steep shores with current and waves, though on the open ocean they are usually in cracks or protected areas. *S. cariosus* can be found often times in aggregations with other individuals, and can be tall and narrow when in large groups. The main exterior has six wall plates and six cirri which are bi-ramus (having two branches per cirral stump) that come out of the opening plates (Cowles 2006). Since cirri need to work in variable flows of water, it is important for them to be able to adapt to different flows for optimal feeding and cirral protection. Phenotypic plasticity is the ability for an organism to change their phenotype of some trait due to an environmental change, and is a possibility for the difference in cirral length and form in different barnacles even within the same species, as well as food availability (Marchinko 2003). For this experiment, the hypothesis was: for barnacles in more exposed areas with higher wave action, the cirri will be shorter than those of barnacles in more protected areas.

Methods/Materials

Barnacles were collected from two different areas in Coos County, Oregon with differing wave exposure and protection. The first collection location was Fossil Point, which is a relatively protected area from waves. It was not nearby the open ocean or any substantial wave action. *S. cariosus* were collected from the high to mid/high intertidal on a large rock formation about 1.0 m high from the sediment on the top of the rock.

The second location was North Cove, Cape Arago which is a much more open location exposed to the open ocean and heavier wave action. *S. cariosus* were collected again from the top portion of a large rock, but within several crevasses in the rock. They were taken from two different locations; one group from the high intertidal and one group from the higher end of the mid intertidal, and both from rocks roughly 1.5 m in height. This sample was slightly larger than the sample from Fossil Point. All barnacles were removed from the rocks with a thin, flat, metal scraper by getting in between their base and the rock and scraping off the rock.

Once in the lab, many *S. cariosus* were already dead and those remaining were put in freshwater prior to dissection, so all were dead upon dissection for equivalence. For the dissection, the diameter of the base openings were measured in two places with a clear, flexible ruler in mm and averaged. Then from the base of the plates, forceps were inserted into the soft tissue. The body and cirri were then exposed and removed from the opening plates and rostrum. The body and cirri were placed underneath a dissecting scope on a large Petri dish with a small amount of water, and the penis was located, since it separates the left and right cirrus number six. For consistency, the sixth cirri were used in every measurement. Once the sixth cirri were located and separated, the same clear ruler was inserted into the dish next to the cirri and bent to fit in the dish for measurement in mm, and the cirri were straightened out by a sharp probe. In all cases, the left and right cirri were the same length, so one number was recorded.

Since many of the barnacles were different sizes between the two locations, enough to affect the size of cirri, the cirral length was divided by the average base diameter to get a single, accurate ratio to represent the cirri as related to the size of the barnacles.

Results

For the barnacles in the protected area of Fossil Point, average cirral length to base ratio was 0.387. The cirri were thinner and a white/pink color than the sample from North Cove. For the first individual, the cirri: base diameter ratio was 5mm/14mm respectively giving 0.357. The second was 4mm/12.5mm giving 0.320. The third was 3.8mm/13mm resulting in 0.292. The forth was 3.5mm/13.5mm giving 0.295. The fifth was 4mm/13.5mm resulting in 0.296. The sixth was 5mm/9.5mm giving 0.526. The seventh was again 5mm/9.5mm resulting in 0.526. The eighth was 4mm/11.5mm giving 0.348. The final was 5mm/9mm resulting in 0.556.

For the more wave exposed sample from North Cove, Cape Arago; the average ratio of cirral length was 0.344. The cirri were blacker in color and slightly thicker than those from Fossil Point. For the first individual, the ratio was 6.5mm/22.5mm giving the ratio of 0.289. The second was 7.1mm/21mm resulting in 0.338. The third was 6.3mm/20.5mm giving 0.307. The forth was 5.4mm/21mm resulting in 0.257. The fifth was 5mm/20mm giving 0.250. The sixth was 7mm/17mm resulting in 0.412. The seventh was 6.5mm/20mm giving 0.325. The eighth was 6.2mm/18.5mm resulting in 0.335. The ninth was 6.1mm/1.4mm giving 0.436. The tenth was 6mm/15.5mm resulting in 0.387. The final was 6mm/13.5mm giving 0.445.

Figure 1: Fossil Point cirral length/base diameter ratio of *Semibalanus cariosus*

Individual #	Cirral Length (mm)	Base Diameter (mm)	Ratio (Cirral length/base diam.)
1	5	14	0.357
2	4	12.5	0.320
3	3.8	13	0.292
4	3.5	13.5	0.259
5	4	13.5	0.296
6	5	9.5	0.526
7	5	9.5	0.526
8	4	11.5	0.348
9	5	9	0.556

Figure 2: North Cove, Cape Arago cirral length/base diameter ratio of *Semibalanus cariosus*

Individual #	Cirral Length (mm)	Base Diameter (mm)	Ratio (Cirral Length/Base Diam.)
1	6.5	22.5	0.289
2	71	21	0.338
3	6.3	20.5	0.307
4	5.4	21	0.257
5	5	20	0.250
6	7	17	0.412
7	6.5	20	0.325
8	6.2	18.5	0.335
9	6.1	14	0.436
10	6	15.5	0.387
11	6	13.5	0.445

Figure 3: Average Cirral Length/Base Diameter in Fossil Point vs. North Cove Samples

Location	Av. Cirral Length/Base Diameter Ratio
Fossil Point	0.387
North Cove-Cape Arago	0.344

Discussion

The average ratios for the barnacles found at Fossil Point were 0.043 units higher than those found at North Cove, Cape Arago as seen in Figure 3. Since the barnacles at Fossil Point were in more of a protected area and had longer cirri, the hypothesis was supported. Those at the more exposed area of North Cove were shorter on average as seen in Figure 1 and Figure 2. This makes sense because the more waves in an area mean more of a possibility for bending or breaking of the cirri, so they should be shorter and stronger in areas with more wave action.

Another possibility would be if certain individuals needed more feeding time if they live further up the shore, so that may lead to longer cirri for maximum feeding ability for the short time period they are underwater. That may be completely independent of wave exposure. Many other studies have concluded similar results in other species of barnacles. In Hong Kong, a study found that for Acorn Barnacles, wave exposure did have a large impact on cirral length. On semi-exposed shores, the cirral length was four percent longer than the exposed shore barnacles. Feeding style did seem to also play a role in the cirral length in the study (Chan 2005).

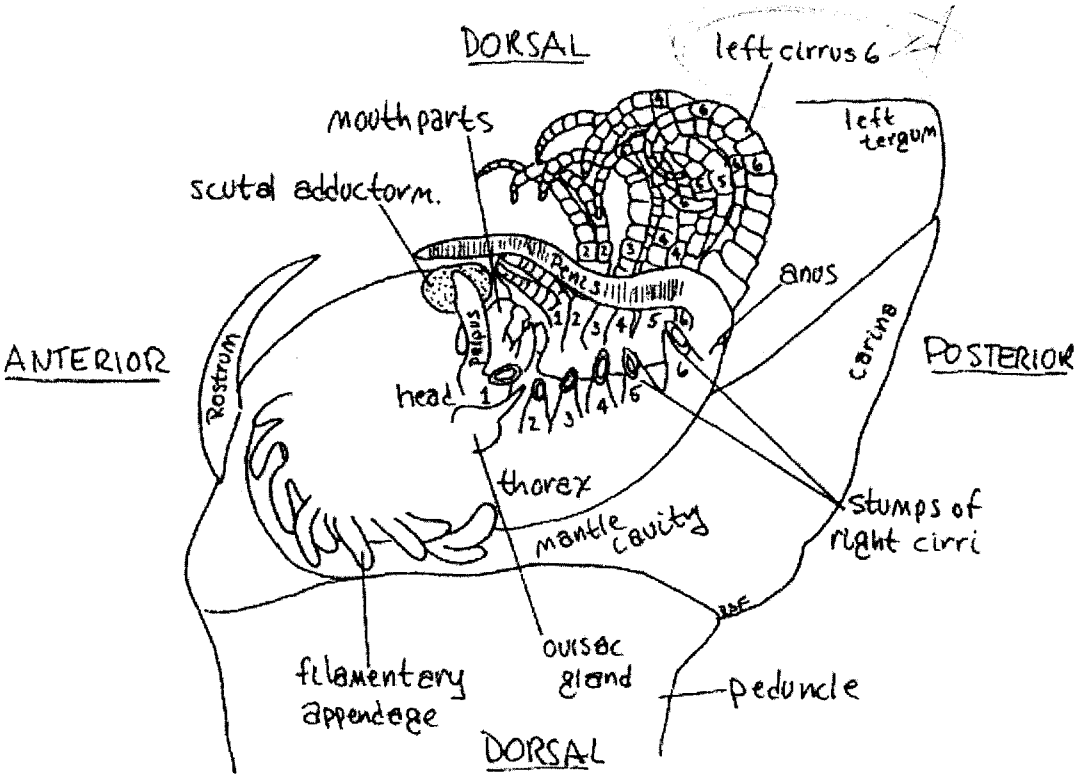
Another possibility for cirral length could have been the issue of drag underwater. Drag increases as the square of fluid velocity, so with an increase in wave exposure there is also an increase in drag forces against the organisms. That could have a decrease in cirral length to decrease drag underwater beyond the concern of cirral damage. Another possibility to combat high water flow could be behavior to supplement the length of cirri. For example, cirri have the ability to withdraw in areas with variable flow rates, so size would not have to play as large of a role. In a study done in California, there was a clear difference in the exposed vs. protected areas with an increase in cirral length in the protected areas. Also, protection from cirri buckling in the waves conflict with the need for the largest cirral net possible for optimal feeding (Miller 2007).

Possible errors in this experiment could have been the difficulty in straightening out the curved cirri to measure them properly. The same technique was always used, but a more precise way to measure perhaps with a more complex dissecting scope would have been better. Also, there was not a large enough sample size of barnacles to make

the results significant. Finally, more calculations should have been done to determine exactly what the percent difference of cirri was between exposed vs. semi-exposed areas.

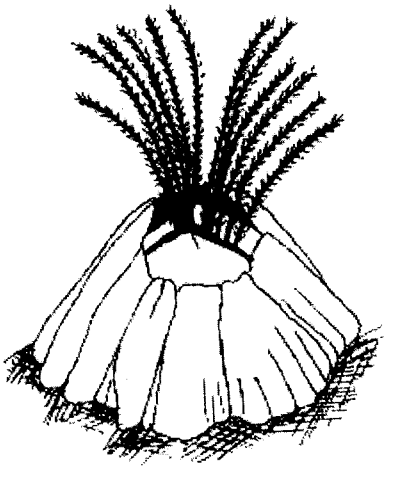
So overall, there was a correlation between cirral length and exposure areas for *Semibalanus cariosus*, as the averages in Figure 3 show. The more exposure to waves showed shorter cirral length. The exact reasons for this are difficult to tell, but protection of cirri and feeding do seem to play a large part. In the future for an experiment, more barnacles should be collected and the age should be determined for the individuals by counting cirral segments to have more precise results. Young age could mean shorter cirri if they have not grown as much yet. Also, exact wave exposure information should be collected about the location where the samples were found for a more accurate picture of the barnacle habitat and conditions both with waves and time spent out of the water not feeding.

Examples of Barnacle Cirri in feeding position



http://webs.lander.edu/rsfox/rsfoximages3/barnacle

http://www.mbayaq.org/efc/living_species/organism_images/lsl



http://www.glf.dfo-mpo.gc.ca

Works Cited

Chan, Benny K. K. and Hung, O.S. 2005. "Cirral Length of the Acorn Barnacle *Tetraclita japonica* (Ciripedia: Balanomorpha) in Hong Kong: Effect of Wave Exposure and Tidal Height". Journal of Crustacean Biology. 25 (3): 329-332

Cowles, Dave. "Semibalanus cariosus". p. 1-2. 07/23/2008 www.wallawalla.edu/academics/departments/biology/rosario/inverts/Arthropoda/Crustacea/Maxillopoda/Cirripedia?Semibalanus_cariosus.html

Fisheries and Oceans Canada. 01/18/2006. www.dfo-mpo.gc.ca. 07/23/2008

Ingram, Joyce. "Knowing Nature...Biography of a Barnacle". Comox Valley Naturalists society. p. 2-3. 2007.www.comoxvalleynaturalist.c.ca/knowing_nature /2007/ barnacle

Lander University. www.webs.lander.edu/rsfox/refoximages3/barnacle. 07/23/2008

Marchinko, Kerry B. 2003. "Dramatic Phenotypic Plasticity in Barnacle Legs (Balanus glandula Darwin): Magnitude, Age Dependence, and Speed of Response". Evolution. 57 (6): 1281-1290

Miller, Luke P. 2007. "Feeding in extreme flows: behavior compensates for mechanical constraints in barnacle cirri". Hopkins Marine Station. Marine Ecology Progress Series. 349: 227-24

Monterey Bay Aquarium. 2008. www.mbayaq.org/efc/living_species/organism_images/Isl. 07/23/2008