<u>Shell thickness trends due to wave action in *Mytilus californianus*</u>

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Introduction— The open coast is an extremely variable environment, and intertidal organisms must be versatile and exceptionally adaptable in order to survive such changing conditions. The California Mussel, *Mytilus californianus*, is a species of mussel which inhabits areas of the rocky intertidal along the Northeastern Pacific coastline from the Aleutian Islands of Alaska to Socorro Island, Mexico.[1] These mussels inhabit the middle intertidal zone as well as areas of the upper intertidal.[2] *M. californianus* is found in very tightly packed beds of individuals. Observation shows that these mussels experience a great deal of exposure to wave action throughout the course of a tidal cycle. While wave action can increase an organism's upper distribution by decreasing their risk of desiccation,[3] wave exposure also increases the physical stress on the protective shells of these organisms.

The shell of *M. californianus* is composed of an inner layer of calcium carbonate and an outer layer of periostracum.[4] Previous studies have shown that mussels with thicker shells are more resistant to predation by animals such as lobsters and crabs, and that the presence of these predators may even induce the mussels to grow thicker shells.[5] These observations led to the question of what effect wave action might have on the thickness of the *M. californianus* shells. This study examined whether wave action causes the shells of *M. californianus* located on the edges of the mussel beds to be thicker than those found at the center of the mussel beds, where more protection is offered by surrounding individuals. This form of adaptability based on location and exposure could be crucial to the survival of these mussels.

Materials and Methods— The mussels used in this study were collected from mussel beds within several rocky intertidal environments at Lighthouse Beach and the South Cove of Cape Arago in Charleston, Oregon. Individuals were collected from the center and edges of mussel beds on both vertical and horizontal rock faces. Nine mussels were collected from each of the two positions being evaluated. All mussels were collected from North-facing rock surfaces. Distinct beds of *M. californianus* were selected, and individual mussels of approximately 6cm in length were collected from the edges and centers of the mussel beds. Selecting mussels of approximately the same size helped to avoid the possibility of confounding data from differences in shell thickness due to the overall size of the mussels.

Once the individual mussels were collected, they were measured using analog vernier calipers to determine their length, height, and also width (see Figure 1 below). The mussels were then opened and cleaned of all tissue. At this time, a hammer was used to crack the shell, allowing the calipers to be inserted to measure the center of both shell valves. Another point, near the edge of the shell valves opposite the hinge, was also measured as a second point of reference (Figure 2). Statistical analysis included determination of the mean and

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[1] Shaw, William N., Thomas J. Hassler, and David P. Moran. "Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Southwest)—California Sea Mussel and Bay Mussel." *U.S. Fish and Wildlife Service, Biological Report 82(11.84).* U.S. Army Corps of Engineers, TR EL-82-4, 1988, 1.

[2] Robles, C., D. Sweetnam, and J. Eminike. "Lobster Predation on Mussels: Shore-Level Differences in Prey Vulnerability and Predator Preference." *Ecology*, 71(4) Aug. 1990, 1565.

[3] Harley, Christopher and Brian Helmuth. "Local- and regional-scale effects of wave exposure, thermal stress, and absolute versus effective shore level on patterns of intertidal zonation." *Limnology and Oceanography*, 48(4), 2003, 1505.

[4] Harper, E. M. "Are calcitic layers an effective adaptation against shell dissolution in the Bivalvia?" *Journal of Zoology*, 251, 2000, 185.

[5] Robles, et al, 1564.

standard deviation of all mussels collected from the edge of the mussel beds, and a separate mean and standard deviation analysis from those collected from the center of the mussel beds.

Results— Measurements showed a clear difference between shell thickness of the edge and center mussels. The shells of the mussels located on the edges of the mussel beds were clearly thicker than those of the mussels from the center of the beds. The sizes of the mussels collected from both locations, however, were quite similar. Table 1 shows the mean length, height, and width of the mussels collected. Analysis of the standard deviation shows that the mussels were not statistically different in size from each other.

Table 1: The average size of the mussels, measured in terms of length, height, and width.

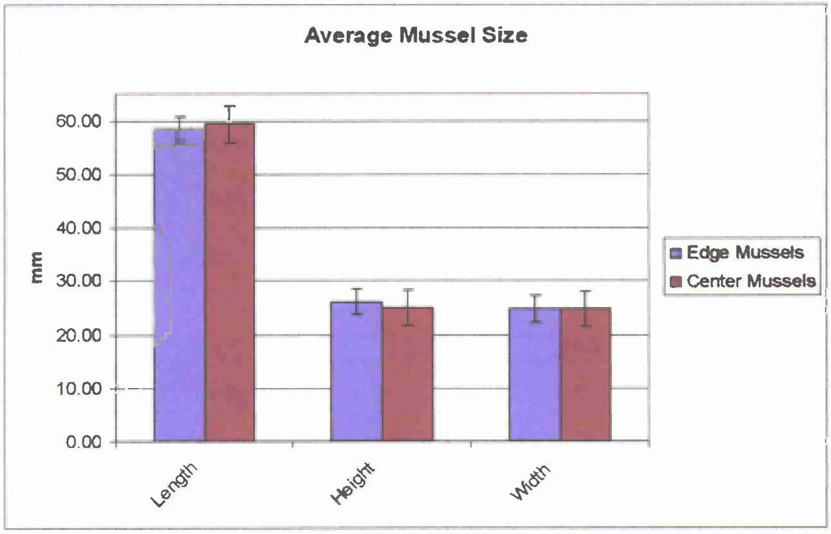
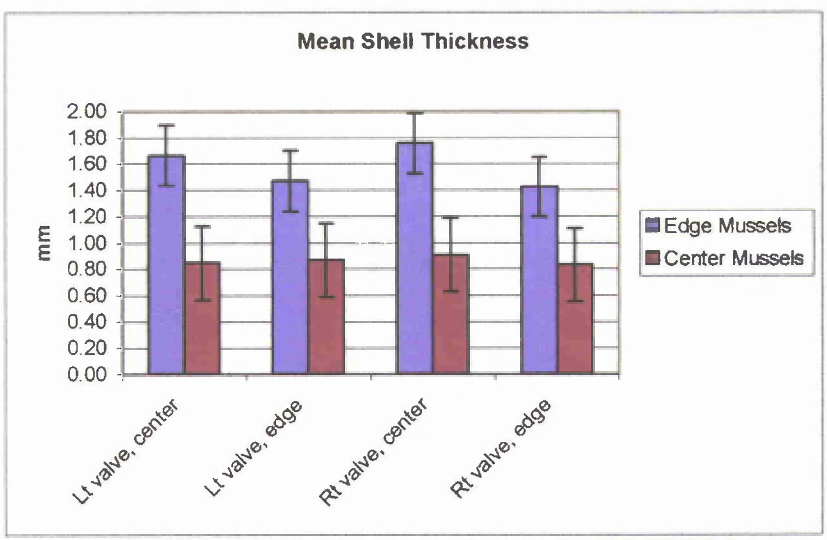


Table 2 shows the measurements of both locations on both shell valves. Although there was some variation between the two valves of the mussels, these differences were not significant. Differences between the edge and center individuals, however, were indeed statistically significant. The edges of the shells were somewhat thinner than the center of the shells, but only in the mussels located on the edge of the mussel beds and not significantly so. The shell thicknesses of the mussels from the center of the mussel bed were nearly equal at both measurement locations on the shell valves.

Table 2: Measurements at both locations on each shell valve of center and edge mussels.



Discussion— The results of this study show that there is indeed a statistically significant difference in the thickness of *M. californianus* shells from the outer edges as compared to the shells of mussels from the center of the mussel beds. This trend is presumably due to protection from wave action experienced by the mussels at the center of the bed. Mussels on the edges, on the other hand, must be better able to resist the force of the waves they are so often exposed to without protection from the other individuals within the mussel bed. This ability of the mussels to secrete a thicker shell due to exposure to wave action or predation, as described above, is evidence of this species' adaptability. The constantly changing conditions these organisms face, from wave action to exposure to desiccation and temperature changes, all require that these mussels be capable of phonotypical plasticity to suit themselves to these variable surrounding conditions. Thus, these variations in shell thickness show the ability of these mussels to adapt to various environmental and biological conditions.

The sample size of this experiment was fairly small. A larger sample size containing individuals from more diverse habitats which *M. californianus* inhabits might provide even more conclusive evidence of this trend in shell thickness. Similarly, experiments could be completed in a laboratory setting with a wave machine to determine the pattern of shell thickening caused by such exposure. It would also be interesting to examine the shells of mussels from different regions and environments along the Northeastern Pacific coast, as well as different zones of the intertidal, or on different faces of rocks (i.e. North-faces versus South-faces of rocks). It seems likely that this pattern of shell thickness would be evident in all of these environments, but it would be interesting to see if any further variation and adaptability exists among these different conditions.

References—

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Figure 2: Internal view of shell with locations of thickness measurements.