Relationships between ambulacral surface area and arm strength in sea stars

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Adaptations of marine organisms

Introduction:

Organisms of the phylum Echinodermata can be found throughout the world's oceans and coastlines. The sea stars, in the class Asteroidea, are some of the most easily recognizable. This is largely because for many of them the rocky intertidal zone is where they make their home. This beautifully scenic habitat, however, is not always the easiest place for organisms to inhabit. On a daily basis sea stars will face the struggles of predation, competition for food, or even desiccation if they become trapped when the semi-diurnal tides of the Pacific Northwest go out. Harmful UV exposure can quickly dry out and kill a sea star that has been isolated for long from the water. In sea stars their mobility is also dependant on contact with water. Their primary form of mobility are the podia or tube feet found on their oral undersides. In most sea stars the podia terminate in adhesive discs which attach via suction (Smith 1946). These tube feet are powered by a hydraulic internal system known as the water vascular system. Sea water is circulated via canals which enter podia and can extend or retract the tube feet with the help of connecting muscles. The tube feet are contained within the ambulacral grooves that run all along the oral surface of the organism's arms. The ability for sea stars to cling to objects like rocks becomes very important especially in rougher coastal areas like the Oregon coast. For many sea stars the ability to cling to a preferred area can be the difference between surviving or not. My investigation chose to look at variations within local sea stars of the midlittoral and infralittoral zones. The purpose was to study the structural characteristics of the ambulacra groove in relation to arm gripping strength on a variety of different substrates. The decision of which five species to test came down to those subjects having only five arms and their availability to test. There are some common species of sea stars like *Pycnopodia helianthoides* and *Solaster dawsoni* that have roughly twenty four and thirteen arms, respectively. I hypothesized that the greater surface area that ambulacra grooves of a sea star have would correspond to greater gripping strength of one of their arms. This study focuses on the structural differences that occur among the most common sea stars found in the Pacific Northwest. It is the goal of studying structural adaptations that we gain a greater understanding of our local ecology and the patterns within it.

Methods:

From the specimens of Asteroidea that were available in our lab I choose to test; *Asterina miniata, Dermasterias imbricata, Henricia leviuscula, Pisaster ochraceus,* and *Evasterias troschelii.* All of the specimens are five armed inhabitants of the infralittoral to midlittoral zones of the rocky intertidal areas of the Oregon coast. Of the four substrates to test grip strength with I choose "clean" rocks, rocks with encrusting sponges, barnacle beds, and mussel beds. The basis for my choices came from field observations of where I'd previously observed most sea stars. The surface areas of an oral sided arm and an ambulacra groove were painstakingly calculated using the author's previous knowledge of calculus. In order to test gripping strength of four of the weaker sea stars I constructed a tension gauge using springs and other equipment. The makeshift gauges were calibrated using common fishing weights to measure distances pulled on my scale. One species required an Hom's tension gauge of much higher strength. I defined freeing an arm from a substrate as the point in which there were no podia connected on that particular arm. Each test was done at least three times on all four substrates with the averages being recorded. All of the tests were done in the field with both the substrates and specimens being only partially submerged in the water. I allowed each specimen roughly ten minuets before each test to give it adequate time to stick to each substrate.

Results:

The results of the averages of the grip tests covered a very large range of values. In general four of the species displayed relatively close results for tension strength while the outlier being *P. ochraceus*. The averages for *P. ochraceus* on all four substrates displayed an exponentially larger ability to grip then the other four species of sea star. The purple star exhibited roughly one hundred times more grip strength than the blood and bat stars did. It also exhibited roughly ten times the holding strength than the leather and troschel's stars. The surface areas for the ambulacra grooves are recorded on their specific sketches. The surface area values are fairly close to one another as compared to the great disparity within their grip strengths. The greatest difference between ambulacra groove areas was between *P. ochraceus* and *H. leviuscula*, 3.41cm squared and .69cm squared respectively.

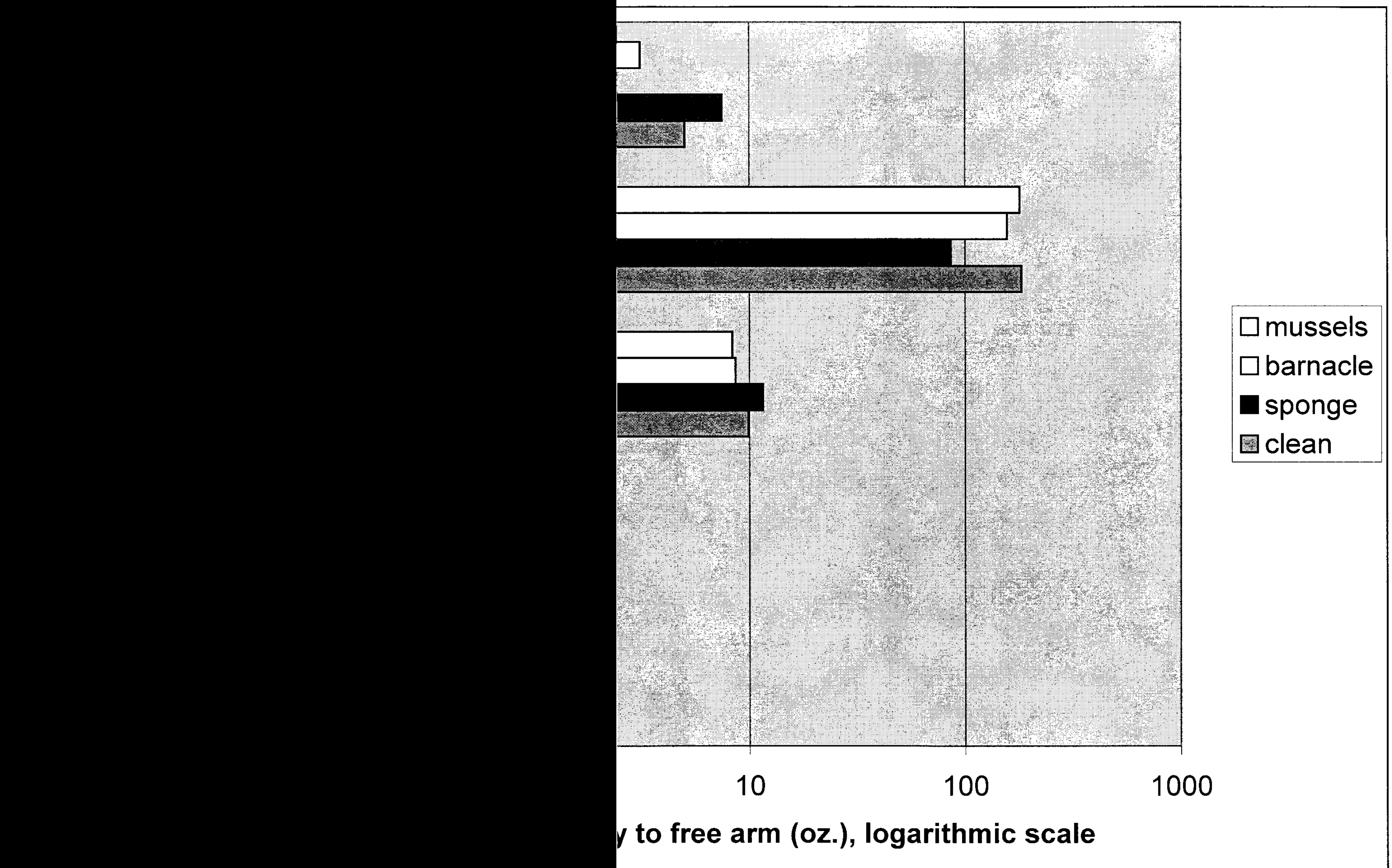
Discussion:

I believe the results clearly show the disproving of my null hypothesis. The expectation from my hypothesis was that as the surface area of the sea stars oral ambulacra grooves increased, so too would the arm's ability to grip to the substrate. I found from my testing that the surface area of ambulacra groves does not clearly interrelate to the gripping strength among these five species of sea star. I believe this demonstrates the importance of testing the tube foot structure further. Being that there was no clear difference in ambulacra area or arm surface area among the subjects, the key to grip strength must lie in the suction ability of the tube feet and the water vascular system. A recent study revealed three main tube foot morphotypes, i.e., knob-ending, simple disc-ending, and reinforced disc-ending. Analysis of the results suggests that tube foot morphology is influenced by species habitat, but within limits imposed by the evolutionary lineage (Santos,2004). While it is not clear exactly how *P. ochraceus* has the uncanny ability to grip with such strength, most likely this structural adaptation is genetically influenced. However, it appears clear that the relative surface areas of the ambulacra grooves has little connection with the arm grip strength of these five species of sea stars.

Bibliography:

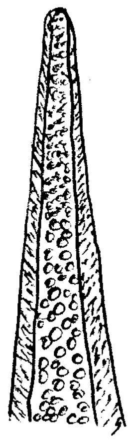
Santos, Romana 2004 "Comparative histological and Immunohistochemical study of sea star tube feet" *Journal of Morphology* issue 3 pages 259-264

Smith, J.E. 1946 "The mechanics and innervation of the starfish tube-foot ampulla system" Phil.Trans. Roy. Soc. London pg.279-310


mussels
barnacle
sponge
clean
10
100
1000
[redacted] to free arm (oz.), logarithmic scale

All drawings done w/out mag

Troschel's Sea Star : Evasterias troschelii

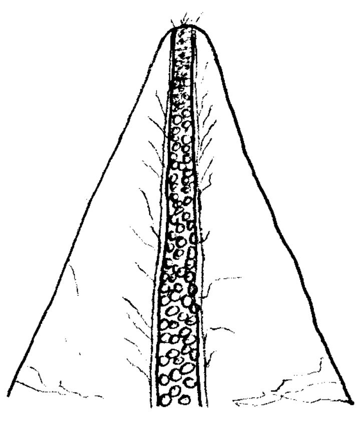


Surface area of ambulacra groove : 2.93 cm^2

5.5 cm base to tip

1.5 cm arm to arm

Leather Star : Dermasterias imbricata

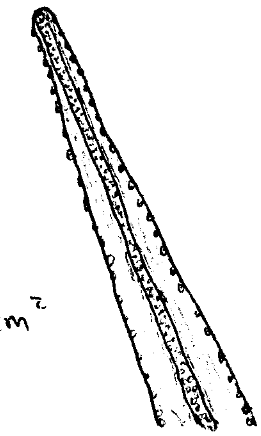


Surface area of ambulacra groove : 1.3 cm^2

5.0 cm base to tip

4.4 cm arm to arm

Pacific Blood Star : Henricia leviuscula

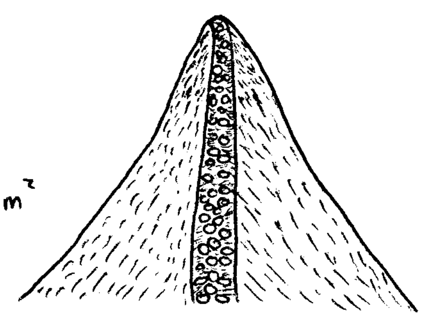


5.2 cm tip to base

Surface area of ambulacra groove : .69 cm^2

1.2 cm arm to arm

Bat Star : Asterina miniata

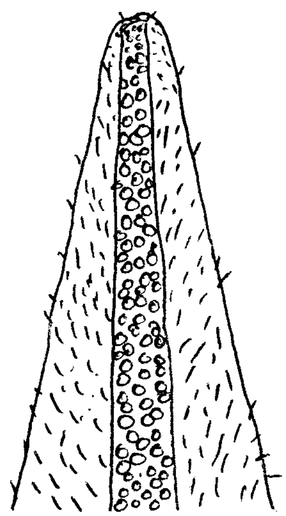


Surface area of ambulacra groove : 1.77 cm^2

3.8 cm tip to base

5.2 cm arm to arm

Purple Star : *Pisaster ochraceus*



6.4 cm base to tip

3.4 cm arm to arm

Surface Area of ambulacra groove : 3.41 cm^2