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Marine Invertebrate Zoology
FHL 432

Evaluating Functional Morphology of Limpets Across Species of the Pacific Northwest

Within the intertidal zone reside limpets, a common gastropod that holds ecological importance (Reguera et al., 2018). They are unique because of their conical-shaped shell with soft tissue only slightly protruding from below. They are very efficient at holding onto the substrate surface with their mucus and muscles as they graze. This is a crucial skill for their survival, as intertidal animals deal with challenges such as desiccation, temperature extremes, and salinity pressures. However, limpets are well-adapted to these challenges due to the structure of their cone-like shell, which provides protection and helps them avoid being swept away by waves (Heller, 2015).

Previous studies have focused on ecological roles of limpets (Denny & Dowd, 2012). However, habitat specialization and the correlation to anatomical features remain understudied (Vermeij, 2020). An important characteristic of limpets is the myostracum, a part of the shell that attaches to a pedal retractor muscle of the foot (Morddyn, 2025). This is effectively moving the shell down over the body to achieve a powerful grip on a rock. This raises the question on how may this differ across different species that reside in different intertidal zones? I aim to understand the differences of shell design between species in the Pacific Northwest. Utilizing microCT scanning technology to obtain a 3D perspective of shell structure and topography. I hypothesize that limpets' shell morphology correlates with species identity because of their habitat and environment.

Across different locations on San Juan Island, limpets of different intertidal zones were collected from Deadman Bay, Cattle point, and a trawl from Kittiwake off the coast on the San Juan Channel. Limpets were keyed out to determine species, then organized into similar sized individuals from each location and species. Six limpets were then chosen to be analyzed through microCT scanning. These included two *Lottia scutum* (Deadman Bay, low intertidal zone), two *Lottia fenestrata* (Cattle Point, mid intertidal zone), one *Lottia digatilis* (Cattle Point, high intertidal zone), and a trawled unidentified species (Kittiwake trawl off San Juan Island). The software 3D Slicer was used to develop an interactive 3D visualization of each limpet. Measurements were taken, anterior to posterior length of shell and the outer anterior part of the myostracum scar to apex length as shown in fig. 2.

The software Slicer uncovered that the Kittiwake trawled gastropod was not a true limpet, but a hat snail *Calyptraea fastigiata*. To evaluate the data I normalized the length of the myostracum scar to apex by dividing the shell length, since these differed between individuals and species. This was important to do in order to make an evaluation between the different species from the different intertidal zones as shown on table 1.

Going from species in the higher intertidal to the lower intertidal there is a trend of increasing the relative scar position to the apex. It is known that lower intertidal dwelling limpets are experiencing more wave exposure and higher access to water, higher intertidal dwelling limpets experience longer dry periods with a higher risk of desiccation. This may correlate with

lower intertidal limpets having a longer relative scar position because water is more accessible and there is not necessarily a need to have a storage within the shell, while more muscle is also indicative of a stronger grip in a high wave and current exposure. While higher intertidal limpets have a shorter relative scar position because there is a higher risk of dessication, and they need to maximize their storage of water within their shell to keep respiration sufficient (Fretter & Graham, 1994). Additionally, the height of the shell is also informative as the *Lottia digatilis* and *Lottia fenestrata* were more taller while *Lottia scutum* was more flat and had a longer mantle skirt. The higher intertidal species are prioritizing volume for water storage than the lower intertidal species which are prioritizing muscle density for anchoring to rocks.

These preliminary results demonstrate that there may be a correlation between the internal shell morphology and the habitat niche. It may be the starting point for further research of the evolutionary adaptation to the different functional morphology in limpets. Additionally, there is a need for a larger sample size and a more diverse species collection. It is important that there is a statistical analysis to support these findings. Limpets are a staple organism of the intertidal ecosystem and further understanding of anatomical functions that support their lifestyle is crucial for conservation and littoral sustainability.

Figures

Table 1

Species	Site	Intertidal Zone	Shell Length (mm)	Anterior scar length (mm)	Relative Scar position
Lottia digatilis	Cattle Point	High	16.03	1.981	0.124
Lottia fenestrata	Cattle Point	Mid	19.33	2.761	0.143
Lottia fenestrata	Cattle Point	Mid	14.97	2.346	0.157
Lottia scutum	Deadman	Low	20.99	4.311	0.205
Lottia scutum	Deadman	Low	20.39	3.260	0.160

Figure 1

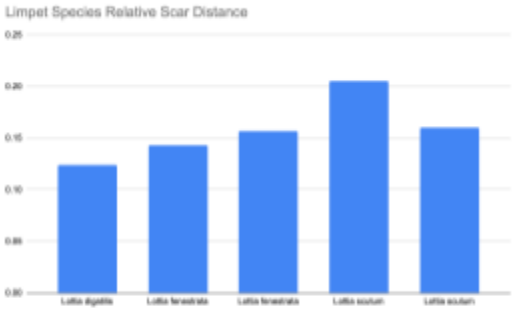

Fig. 1 The relative scar position from the anterior end of the myostracum to the apex, normalized by the individual shell length. This was done by the anterior end of the myostracum to the apex in mm divided by the length in mm.

Figure 2: microCT Scanned Images

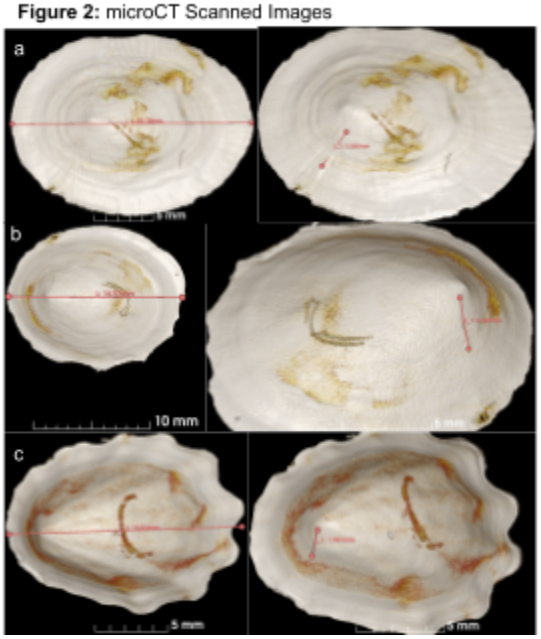

Fig. 2. (a) *Lottia scutum*, measurement of the anterior to the posterior length of shell, and to the right the length of the outer myostracum scar to the apex. (b) *Lottia fenestrata* measurement of the anterior to the posterior length of shell, and to the right the length of the outer myostracum scar to the apex. (c) *Lottia digitalis* measurement of the anterior to the posterior length of shell, and to the right the length of the outer myostracum scar to the apex.

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Denny, M. W., & Dowd, W. W. (2012). Biophysics, environmental stochasticity, and the evolution of thermal safety margins in intertidal limpets. *Journal of Experimental Biology*, *215*(6), 934–947. https://doi.org/10.1242/jeb.058958

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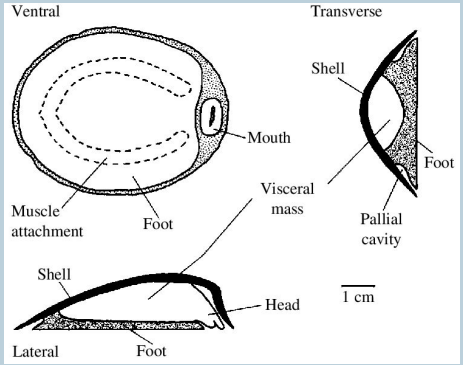
Keywords: microCT imaging, morphology, intertidal

Introduction

What are Limpets ?

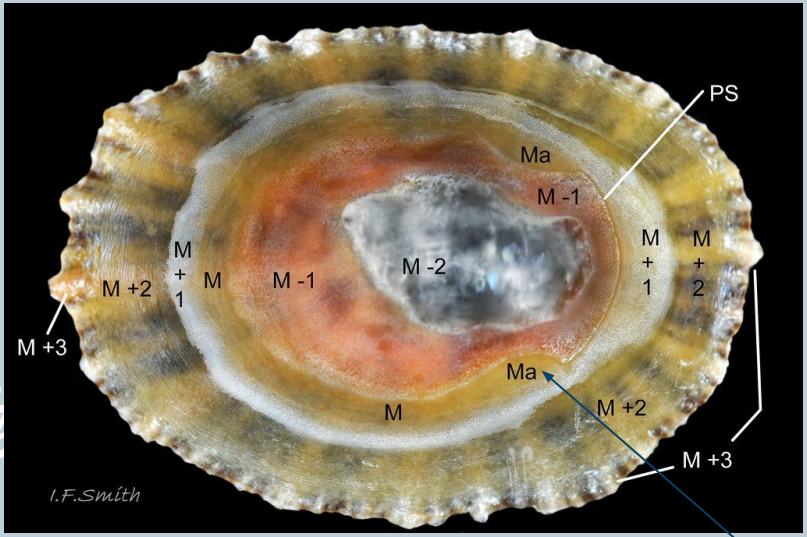
- Marine gastropods with a conical shell
- Intertidal animals and use mucus and muscle to hold on to surface
- Grazers and hold ecological importance



However, habitat specialization and the correlation to anatomical features remain understudied (Vermeij, 2020)

Limpet Powerful Muscle

(M) Myostracum - pedal retractor muscle
- (Ma) anterior end of the myostracum



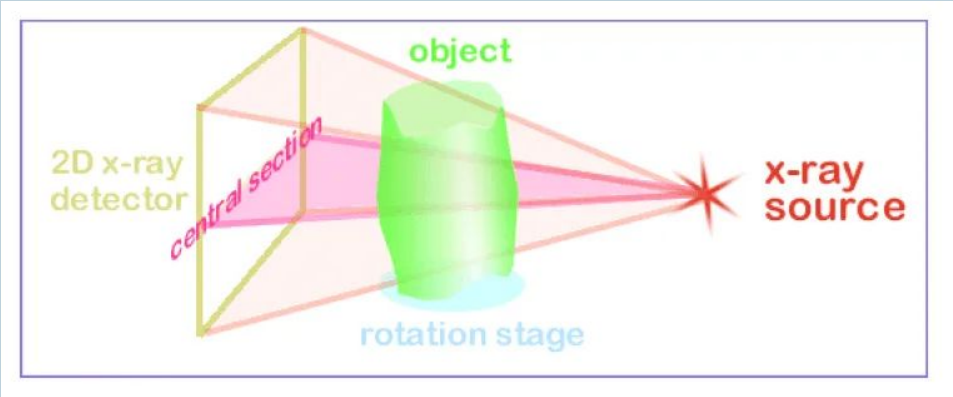
Used to pull the shell down over the body for a tight grip to a rock
- Predator protection
- Water storage

Project Goal

Goal: To investigate and observe differences in functional morphology across different species of Pacific Northwest limpets.

Approach: Utilize micro CT scanning to visualize and measure internal shell structures like the muscle scar position.

Hypothesis: Limpets' shell morphology correlate with species identity because of their habitat and environment



Methods: Field Collection

Collected 6 Limpets, 4 species across zones

Cattle Point: *Lottia fenestrata* (2), *Lottia digitalis* (1)

Deadman Bay: Lottia scutum (2)

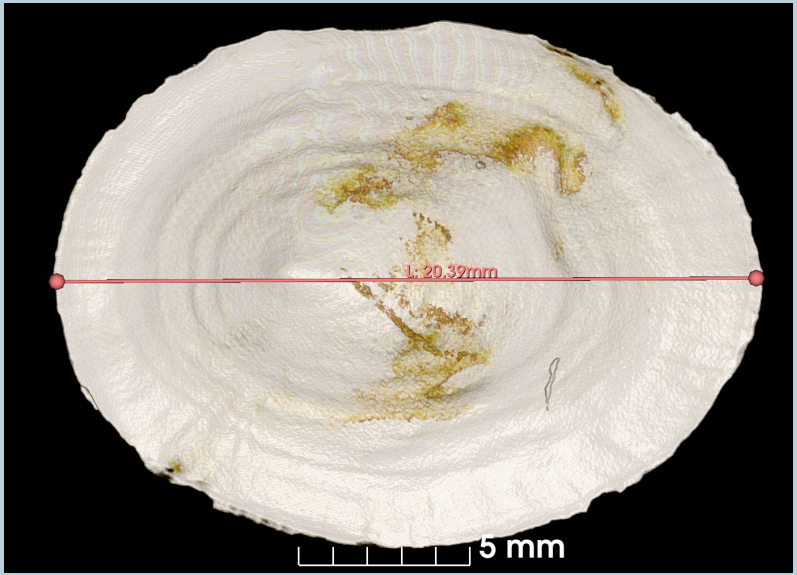
Kittiwake Trawl: ? (1)

Methods: CT Scanning & Analysis

- Limpets were euthanized in $MgCl_2$, minor stain in iodine.
- Packaged and processed through micro CT scanning
- Analyzed through Slicer software

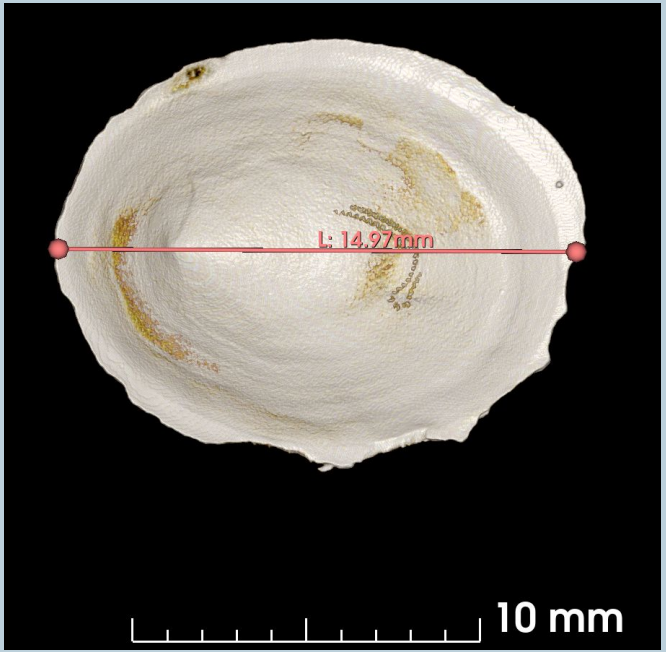
Species	Site	Habitat	n
Lottia scutum	Deadman Bay	Low intertidal	2
Lottia fenestrata	Cattle Point	Mid intertidal	2
Lottia digitalis	Cattle Point	High intertidal	1
?	Kittiwake Trawl	Subtidal	1

CT Imaging



Lottia scutum

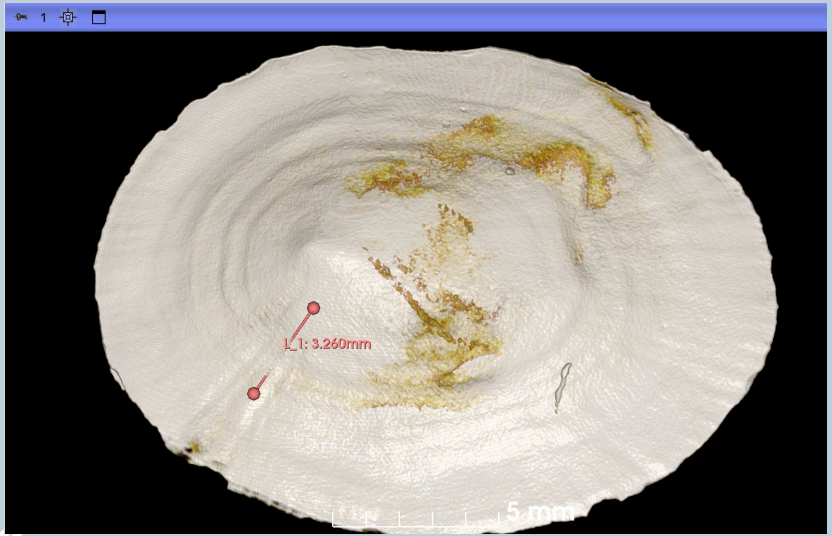
Low intertidal

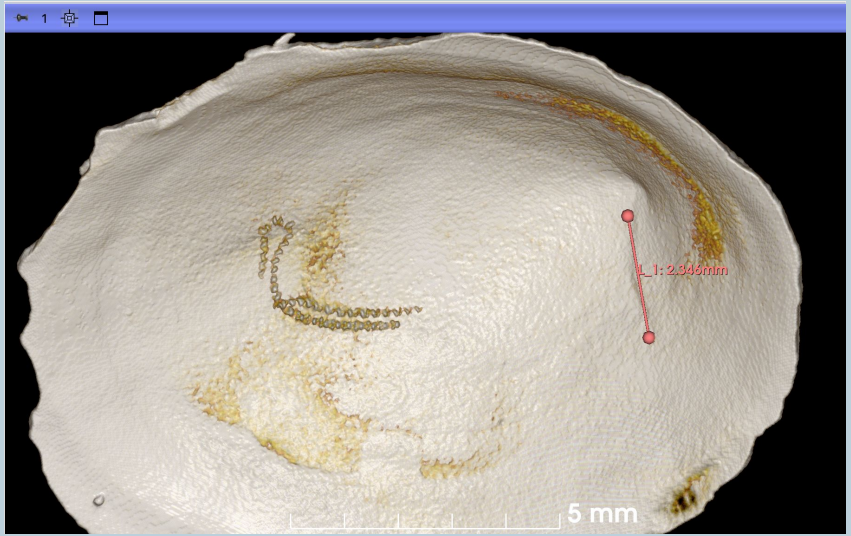


Lottia fenestrata

Mid intertidal

CT Imaging





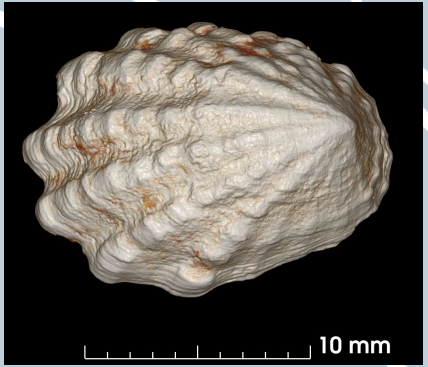
Lottia scutum

Low intertidal

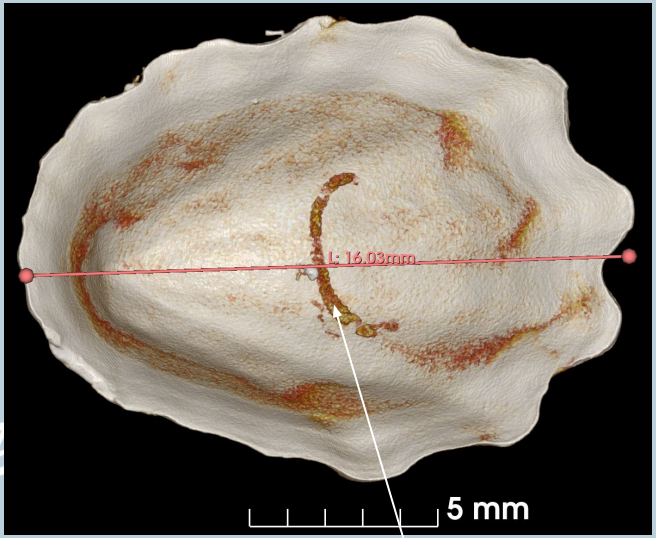
Lottia fenestrata

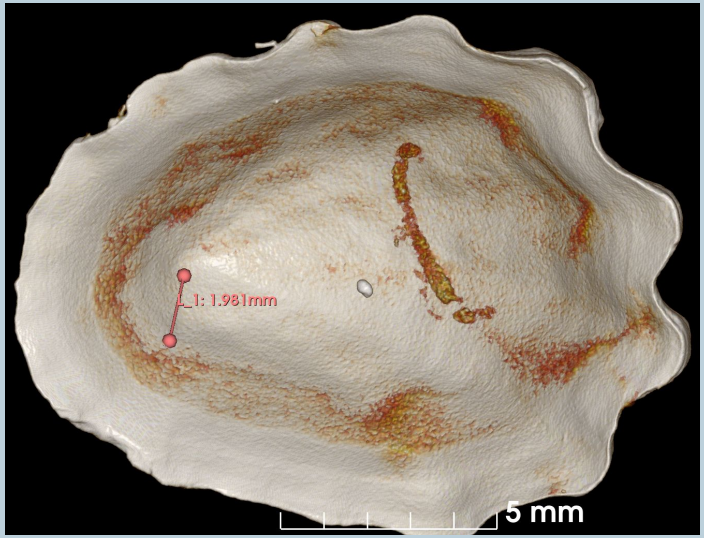
Mid intertidal

Lottia digitalis



High
Intertidal

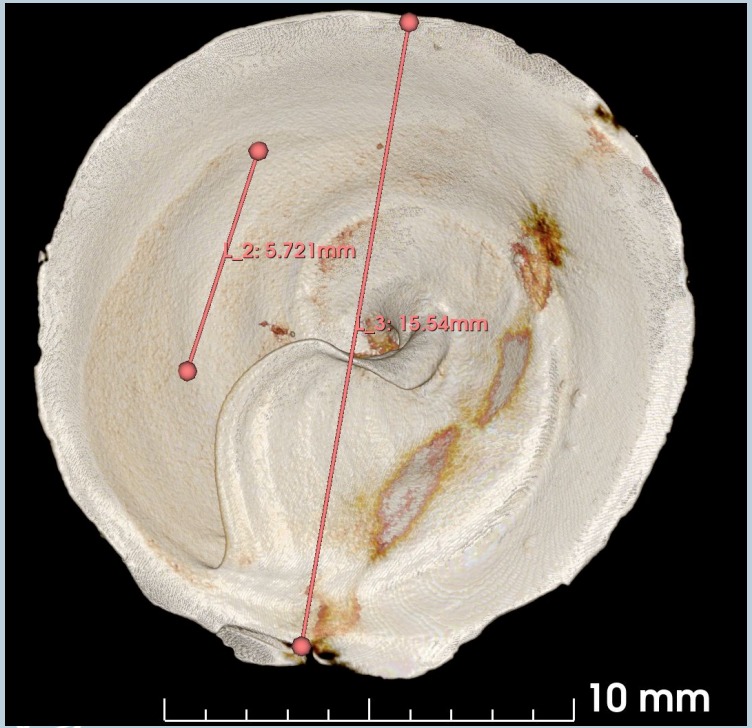




Radula Caecum

Kittiwake Trawl

Not a limpet! *Calyptraea fastigiata*



Results

Utilized the shell lengths to normalize the distance between the apex to the edge of the scar

Species	Site	Shell Length (mm)	Anterior scar length (mm)	Relative Scar Position
Lottia digitalis	Cattle Point	16.03	1.981	0.124
Lottia fenestrata	Cattle Point	19.33	2.761	0.143
Lottia fenestrata	Cattle Point	14.97	2.346	0.157
Lottia scutum	Deadman	20.99	4.311	0.205
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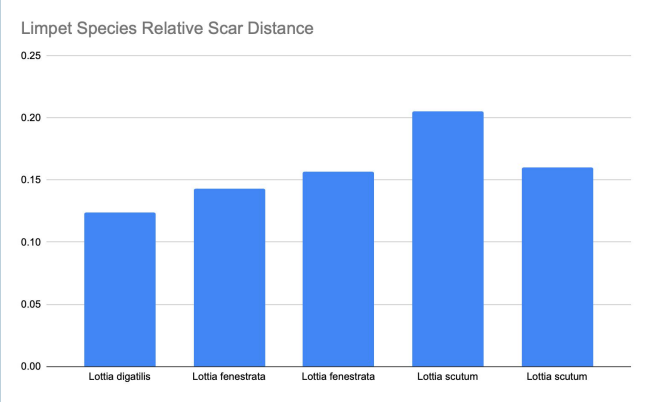
Interpreting Trends

Trend

- Limpets from lower intertidal zones have longer relative scar position
- Limpets from higher intertidal zones have shorter relative scar position

Possible explanation

- Limpets from lower intertidal zones experience more wave exposure and can stay hydrated
- Higher intertidal zone limpets are out of water more often, higher risk of drying out

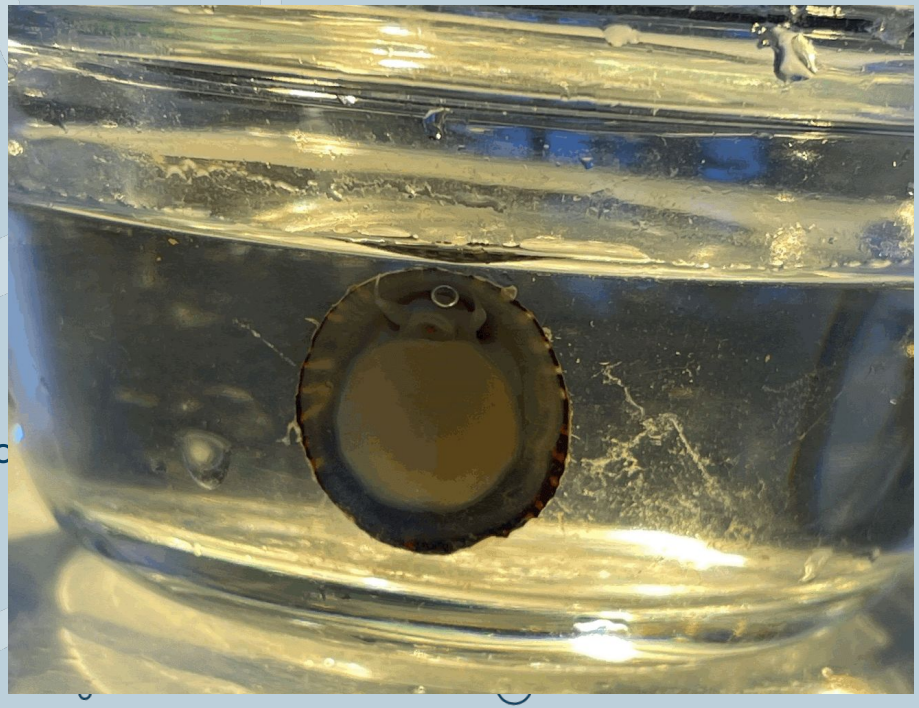


Significance & Future Work

- Possible connection of shell morphology to habitat
- Insight into the evolutionary adaptation and life histories throughout the intertidal zones
- A preliminary step to understanding anatomical functions with habitat specialization

- Increase sample sizes and species collection
- Significant statistical analysis
- Use other approaches of measurement to compare muscle scar

THANKS!



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