

Shaped For Success: Exploring Shell Shape Variation Across Environmental Contrasts in *Littorina littorea* and *Littorina saxatilis*

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Introduction: The Study of Body Shape Variation

Local Adaptation and Body Shape

- **Body shape** plays an important role in **environmental adaptation**
- Littorina - a remarkable example of **phenotypic diversity** in varied environments (Johannesson, 2003; Rolan-Alvarez, 2007)

Littorina saxatilis = Benthic embryo brooding = limited dispersal

Littorina littorea = Planktotrophic larval development = broad dispersal

Research Questions:

- Can we **observe differences in shell shape** within *L. littorea* in exposed and sheltered habitats, or across the vertical gradient?
- How do **patterns** of shell-shape variation **differ** compare between *L. littorea* and *L. saxatilis*?
 - ◆ Application of two different Geometric Morphometrics techniques for shape analysis

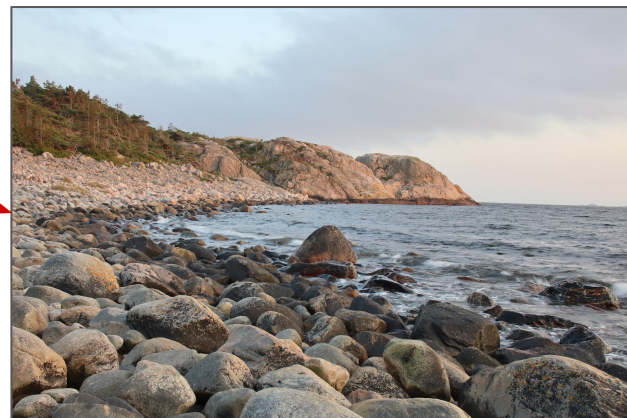
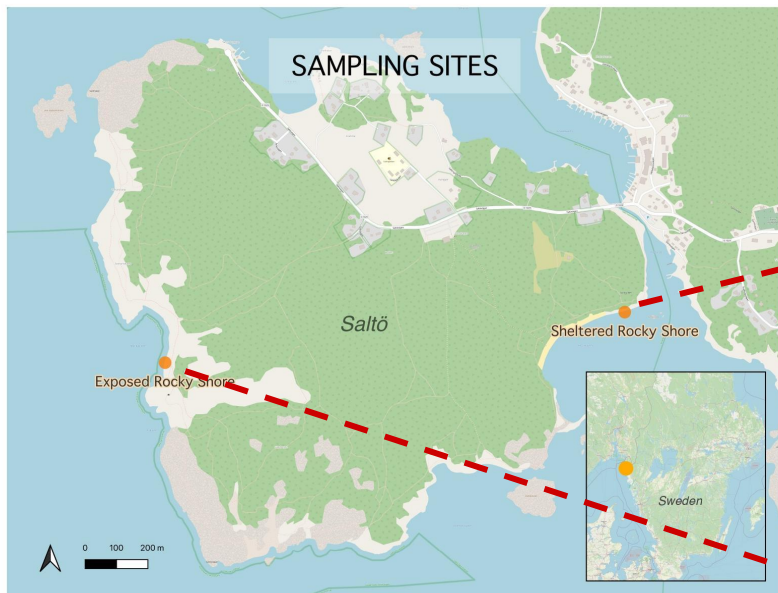
Littorina saxatilis



Littorina littorea



Materials and Methods: Sampling Protocol



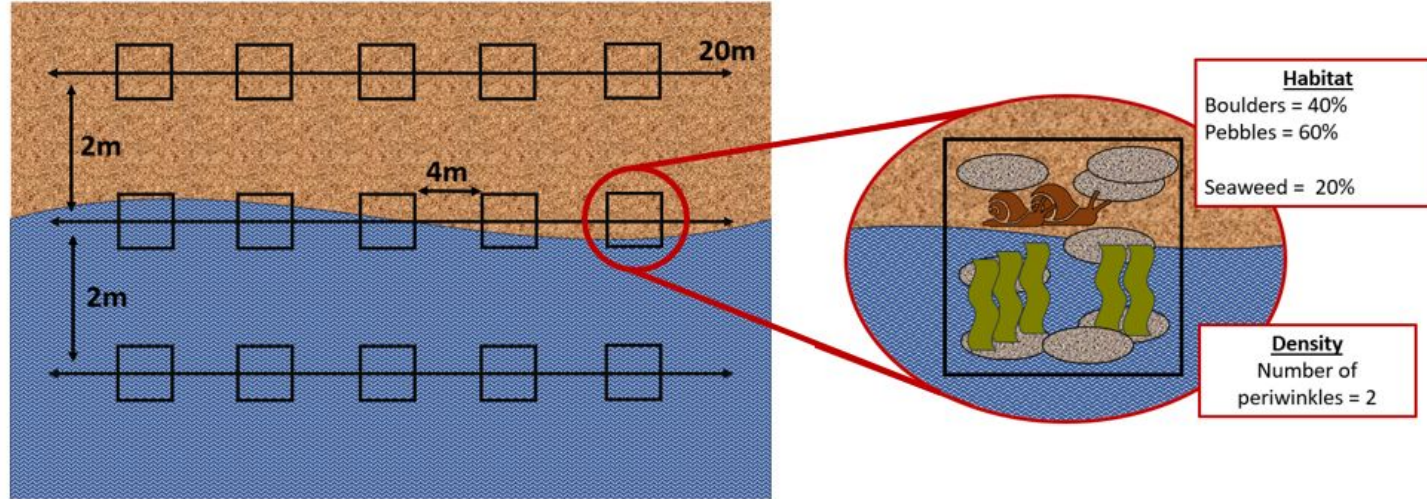
Sites:

- Exposed rocky shore
- Sheltered rocky shore

Vertical Gradient:

- *Upper littoral*
- *Water line*
- *Submerged*

Materials and Methods: Sampling Protocol



+ Pick >15 individuals of each species at each height

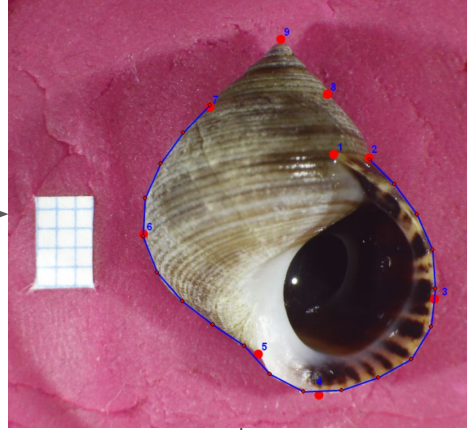
$$15 \times 2 \times 3 = 90$$

x 2 sites = 180 total

Materials and Methods: Image Processing



Snail
sample



Landmark
coordinates (X/Y)

Traditional Geometric Morphometry (GM)

Adams et al. (2019)

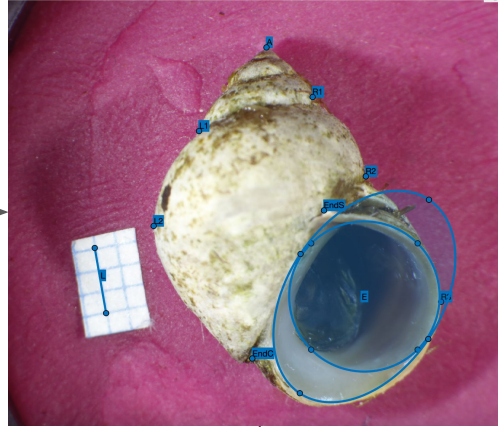
Generalized Procrustes Analysis

**“Procrustes”
Residuals**

Materials and Methods: Image Processing



Snail
sample



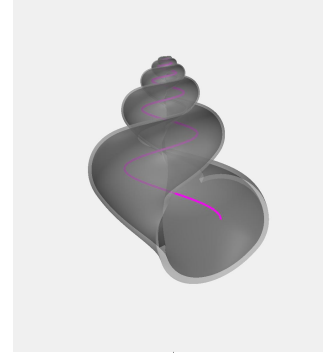
Shellshaper model

$$L(t) = (r_0 e^{g_w t} \cos(t), -r_0 e^{g_w t} \sin(t), -h_0 e^{g_h t}),$$

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Growth-based
shape modelling -
Shellshaper (SS)

Larsson et al. (2020)



Shell growth
Parameters

Results and Discussion: Comparing Mean Shapes

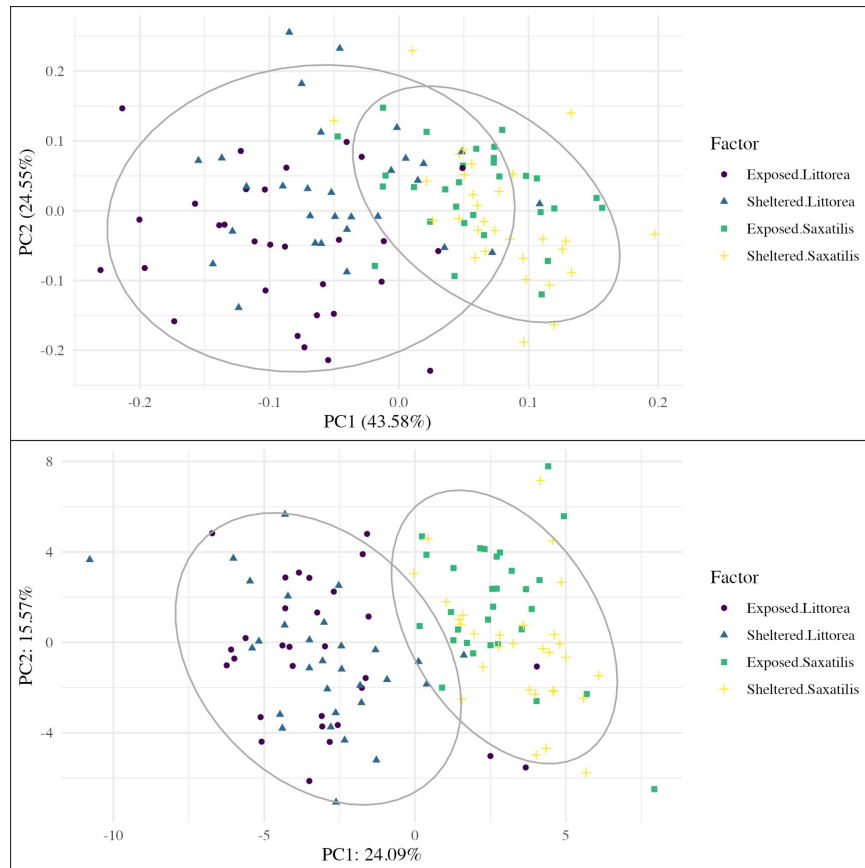
RQ1: Are there shape differences across sites for *L. littorea*?

- **PCA:** Discernible differences between sites and species
- MANOVA to test differences in mean shape:

MANOVA:

- **Both datasets:** Significant differences observed between:

- ◆ **Site:**
(SS: $p = 0.000$, GM: $p=0.008$)
- ◆ **Species**
(SS: $p = 0.000$, GM: $p=0.001$)
- ◆ **Site/species interaction**
(SS: $p = 0.000$, GM: $p=0.010$)



SS dataset
shell growth
parameters

GM dataset
traditional
procrustes
residuals

Results and Discussion: Dispersion Analysis

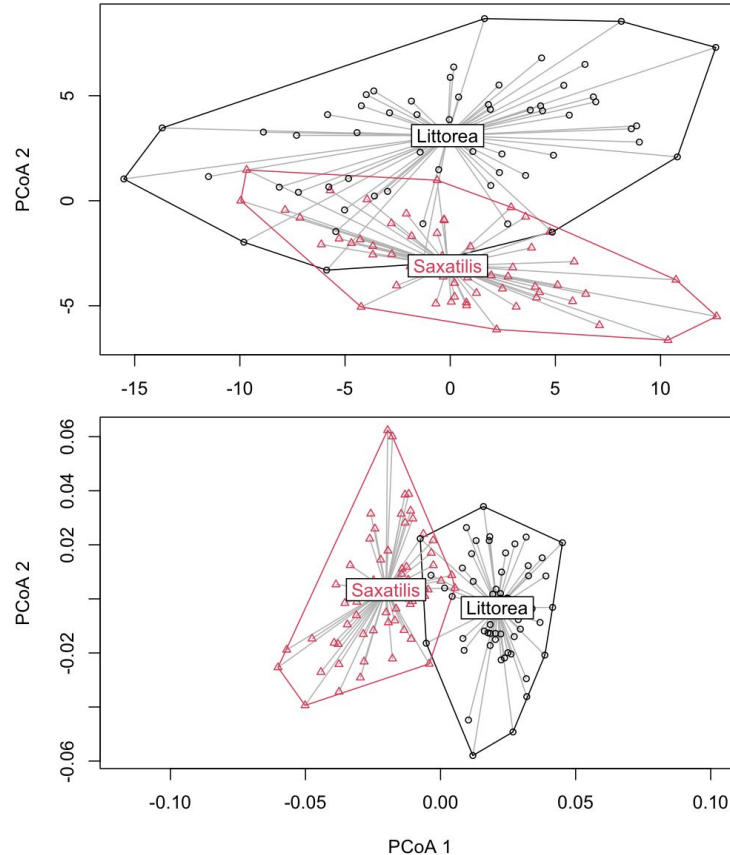
RQ2: How does shape variability compare between *L. littorea* and *L. saxatilis*?

Analysis of Dispersion:

- **Euclidean** distance between **shape centroids** and **group centroids**
- Overall dispersion was significantly different between **species** ($p=0.002$) - only for SS data.
- Dispersions across all other factors and interactions were insignificantly different.

Rejects original hypothesis: less variation in body shape in *L. littorea*

- Link between high dispersal and high plasticity (Hollander, 2008)?



SS dataset
shell growth
parameters

GM dataset
“traditional”
procrustes
residuals

Results and Discussion:

Shape Variability

RQ2: How does shape variability compare between *L. littorea* and *L. saxatilis*?

→ **Plots 1-2:**

Consensus landmarks / sample variation

→ **Plots 1 - 4:** average difference between group shapes relative to overall mean shape

◆ **3: Exposed** - *L. littorea*

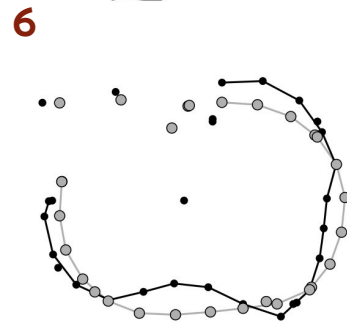
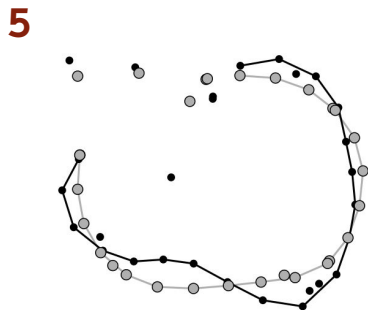
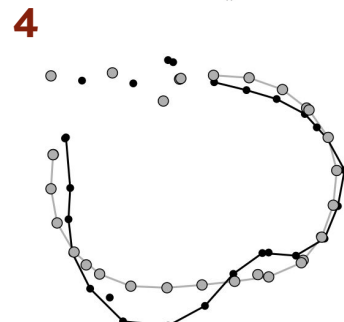
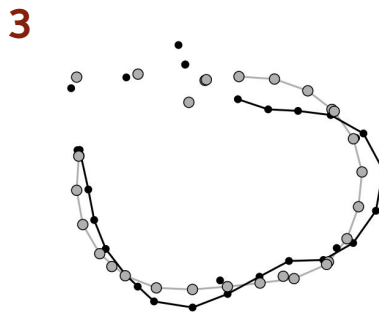
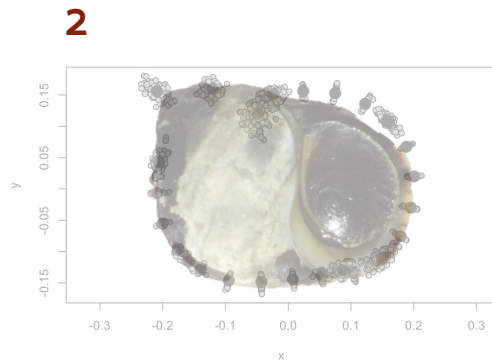
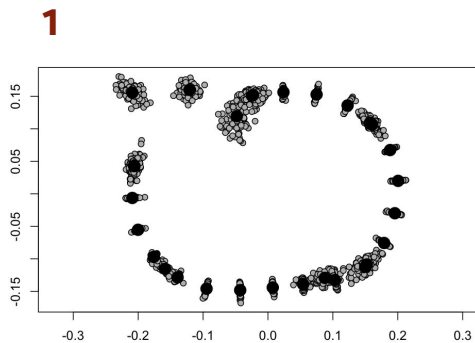
◆ **4: Sheltered** - *L. littorea*

◆ **5: Exposed** - *L. saxatilis*

◆ **6: Sheltered** - *L. saxatilis*

→ *L. littorea* - variation focused on the **shell**

→ *L. saxatilis* - variation focused on the **aperture**
(Johannesson & Johannesson 1996)

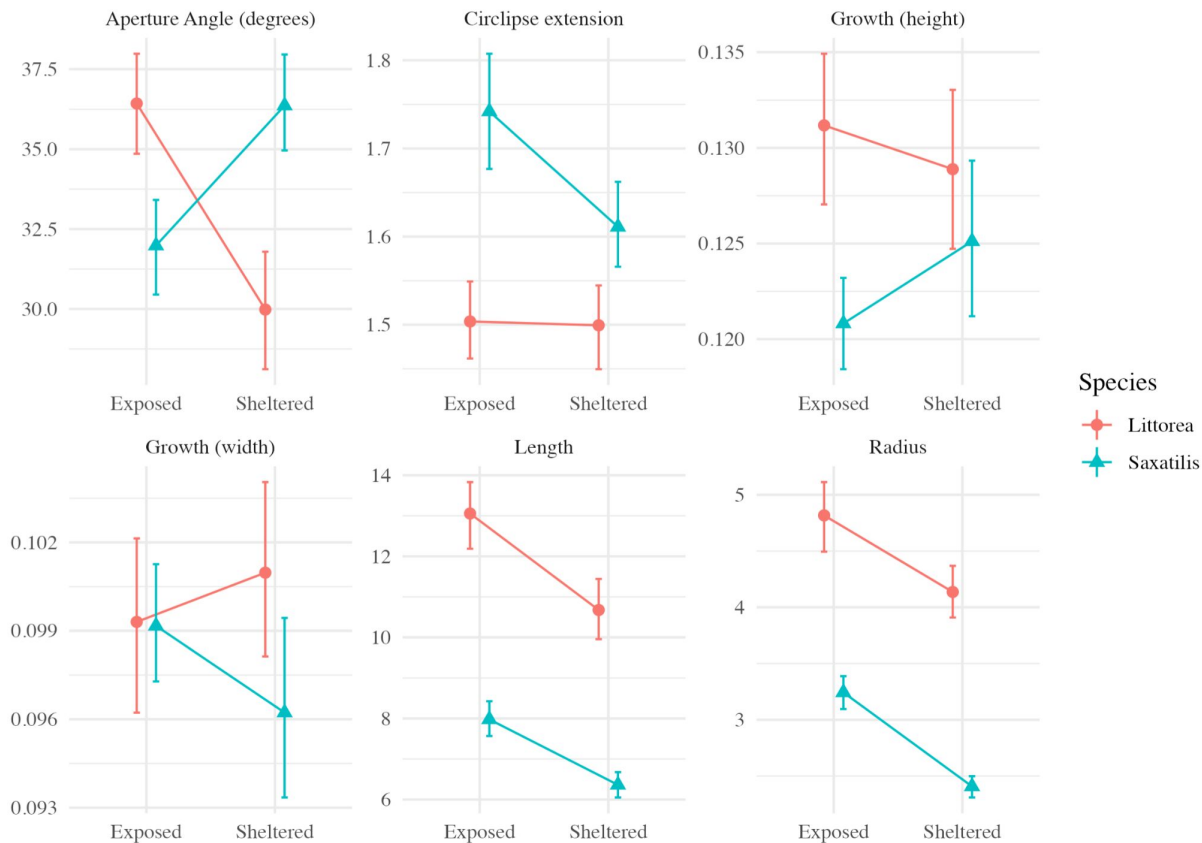


Results and Discussion: Shape Variability

RQ2: How does shape variability compare between *L. littorea* and *L. saxatilis*?

- Change in **growth parameters** (across species and sites)
- Different **trajectories** of change across most variables
- Patterns consistent with GM results:

- ◆ *L. littorea* - changes associated with **shell**
- ◆ *L. saxatilis* - changes associated with **aperture**



Conclusion and Limitations

- **Significant differences** in patterns of shape variation between *L. littorea* and *L. saxatilis*
 - ◆ **Rejected** the hypothesis that variation will be **more distinct** in *L. saxatilis*
- **More variability** in shell shapes within *L. littorea*?
 - ◆ Relationship between plasticity and dispersion?
- Robust **description** of shape response between species:
 - ◆ Starting point for future research examining sources of shape variation
- Suggestions for **future** studies:
 - ◆ More environmental **contrasts** (muddy)?
 - ◆ More detailed **shape/environmental associations**



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"I ate, I drank, I was merry. Now what?"

Thank you!
Any questions?

*Special thanks to **Marta Rufino** for your wonderful guidance and support :)*

All code used for our analysis can be found here:

github.com/saeeshm/littorina-shape-analysis



References

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