Name: Kaya Wurtzel
Class of 2021
Major: Biology
Minor: Religion

Dear Quahog Bay Conservancy,

Thank you for your generosity that made my research possible this summer. With the help of your funding, my lab was able to complete a data set of films that will allow us to better understand the way that flow interacts with the sea star bouncing gait. During this gait, the sea stars use a fraction of their tubular feet, called podia, in coordinated motions to propel themselves forward, in contrast to the relatively uncoordinated movement of podia in the slower crawling gait. The oscillatory gait has been previously filmed and analyzed in three species of sea stars locomoting on flat surfaces at negligible flow speeds. This summer, we developed experiments to help us understand how more variable conditions, such as flow and sloped surfaces, effect locomotion in the local sea star *Asterias forbesi*. Data from our flow experiment indicated that flow causes sea stars to change their direction of travel, their speed and their use of oscillatory locomotion.

I feel lucky to have gotten to spend a summer working with these creatures that we are really just beginning to understand with other people who are just as excited about them as I am. My experience doing research this past summer gave me the chance to develop skills that I know I will continue to benefit from going forward in my future experiences with research in marine science. Again, thank you so much for your contribution that made my research possible.

Best,
Kaya Wurtzel

Impact of Flow on Sea Star Oscillatory Gait

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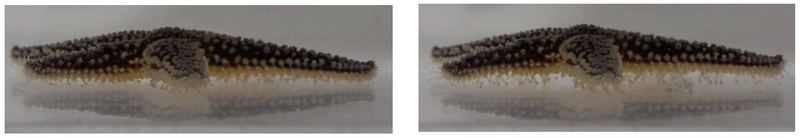
Abstract

In 2014, the Johnson lab discovered that sea stars use an oscillatory gait to move more rapidly. During this gait, the sea stars use a fraction of their podia in coordinated motions to propel themselves forward, in contrast to the relatively uncoordinated movement of podia in the slower crawling gait. The oscillatory gait has been previously filmed and analyzed in three species of sea stars locomoting on flat surfaces at negligible flow speeds. This summer, we developed experiments to help us understand how more variable conditions, such as flow and sloped surfaces, affects locomotion in the local sea star *Asterias forbesi*. Data from our flow experiment indicated that flow impacts sea star locomotion, influencing both the direction of travel and the use of oscillatory locomotion.



Bottom (left) and peak (right) of an *Asterias forbesi* bounce.

Introduction

- Sea stars and other echinoderms move around using hydraulically powered tube feet, or podia.
- Much of the time this movement looks like a crawl, but…
- In 2014, the Johnson/Ellers lab discovered that the chocolate chip sea star, *Protoreaster nodosus,* sometimes uses an oscillatory gait, where coordinated movement of its podia launch the sea star up and down (Ellers et al. 2014).
- Further research identified other sea star species that use this gait: *Asterias forbesi* and *Luidia clathrata,* among others.

- Why bounce? → to go faster! (Johnson et al. 2017)

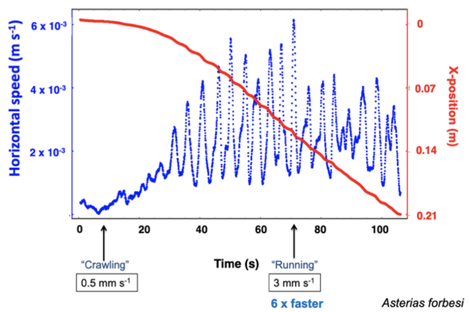


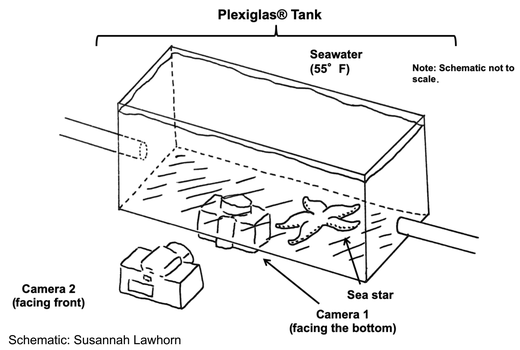
Figure 1. Horizontal speed and x-position of a sea star transitioning from a crawling to a bouncing gait.

- During the bouncing gait, sea stars are going the fastest when they are highest in their bounce.
- This is similar to terrestrial running gaits, but is more like a coordinated pole vault.

Research Goals & Questions

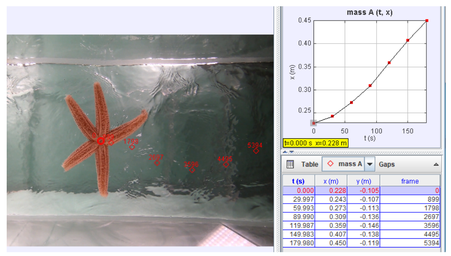
- Before this summer, this gait had only been studied under negligible flow conditions.
- However, sea stars experience variable flow conditions in the wild, so we explored the impact of flow on sea star locomotion.
- Research Questions:
  - What is the effect of flow on sea star locomotion?
  - Assuming flow does have an impact on locomotion, is there an interaction between flow and size?
- Approach:
  - Film *Asterias forbesi* of varying sizes with no flow, and fast flow in two directions and analyze direction of travel, speed, and gait choices.

Methods & Materials



Schematic: Susannah Lawhorn

- Filmed 25 *Asterias forbesi* across a size range, with flow moving right to left, left to right, and with no flow.



- Marked position of sea star every 30 seconds from bottom films in Tracker.
- Calculated average direction of travel, using a mean of circular quantities method.

- Used Rao's spacing test to determine if the set of average angles for each flow condition were uniformly distributed around a circle.
- Analysis: Mathematica was used to process data and for graphing, and R was used for statistics and graphing.

Results & Discussion

Results:

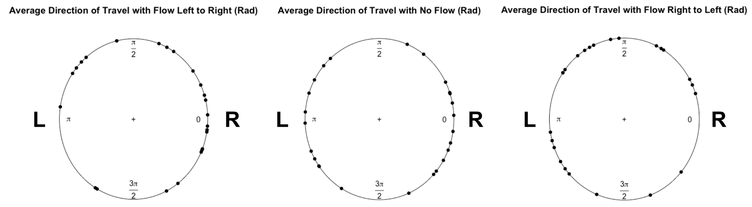


Figure 2. Average direction of travel for 25 *Asterias forbesi* in flow moving left to right, no flow, and right to left.

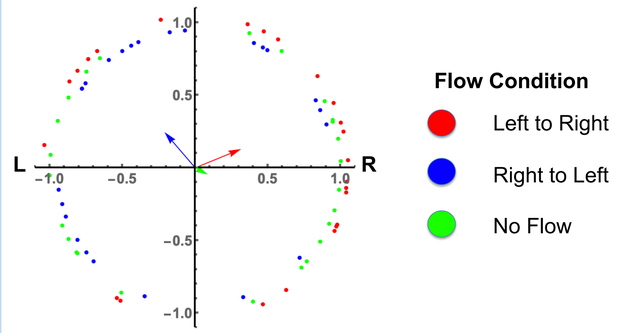


Figure 3. Average direction of travel for 25 *Asterias forbesi* in each flow condition. Vectors show the average direction of travel for all sea stars in each flow condition, with length corresponding to the probability of traveling in that direction given the flow condition.

- Average directions of travel for sea stars experiencing flow left to right and right to left were not uniformly distributed (Rao's Spacing test; $p<0.01$ for both events to occur).
- No evidence to suggest that speeds are significantly different between flow treatments.

Conclusions:

- *Asterias forbesi* has a tendency to travel in a similar direction to flow.
- Flow likely matters for other aspects of the sea star oscillatory gait, influencing how the gait functions in the wild.

Future Work:

- Analyze the impact of flow on the stride length and other movement variables of the oscillatory gait.
- Explore a possible flow assisted bounce, where bouncing may be less energetically expensive in the direction of flow.

Acknowledgements

We would like to thank Marko Melendy and Heidi Franklin for all their assistance with keeping our sea stars happy, the Russack Coastal Studies Fellowship for providing funding to both co-authors, the Life Sciences Fund for supporting Sophie Walton's research and the Quahog Bay Conservancy for their 2019 Marine Science Award in support of Kaya Wurtzel's research.

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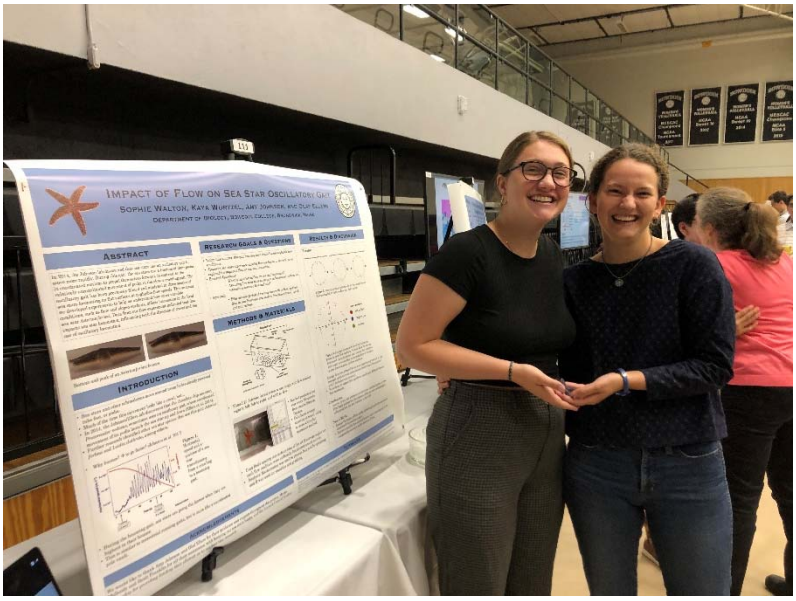

Kaya (R) and Sophie Walton (L) presenting at the President's Summer Research Symposium, October 2019.


Kaya diving for sea stars, July 2019.


Kaya filming sea stars, July 2019.