Effects of Flow Speed and Direction on the Frequency and Speed of Sea Star *Asterias forbesi* Oscillatory Gait

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Locomotion defines a creature's ability to move from one place to another. Sea stars locomote using hundreds of small tube feet (podia) that are controlled by a dispersed, non-centralized nervous system. Sea stars can crawl by striding relatively uncoordinated podia in a similar direction with each other. Podia can also coordinate via mechanical coupling to make sea stars vault up and forward in a faster bounce-like movement called an oscillatory gait [1,2]. Sea star oscillatory gaits have characteristic frequencies and speeds, which have been studied in still water but not in flow. Effects of flow may be negligible at slow flows, disruptive at high flows, and may either down slow or speed up sea star locomotion depending on the speed of flow and the relative directions of flow and sea star. As a first step in understanding the interaction of sea star locomotion and flow, we quantified the frequency and speed of the oscillatory gait of the sea star *A. forbesi* at three flow speeds and two locomotion directions. We hypothesized that *A. forbesi* would move faster with water flowing in the sea star's direction of movement than in no flow and more slowly with flow opposite to sea star movement.

We collected 14 *Asterias forbesi* (33-85 g) from the local intertidal/shallow subtidal and acclimated and maintained them in 13ºC recirculating seawater at the Bowdoin marine lab at the Schiller Coastal Studies Center. We filmed them locomoting using the oscillatory gait at 13ºC in a flow tank at three flow speeds (0, 9 and 13.5 cm s^{-1}) and two locomotion directions that corresponded to against and with flow at non-zero flow speeds. Order of filming sea stars and order of flow conditions for a given sea star on a given day were determined randomly. Time and position data were extracted from 2-6 films of each sea star in each flow condition using DeepLabCut, from which frequency and maximum speed of the oscillatory gait were determined using *Mathematica* programs written by O. Ellers. Statistical analyses on those variables were conducted using SPSS software and graphed using GraphPad Prism. Preliminary results show that at the highest flow speed frequency and maximum speed differed when locomoting against flow and increased when locomoting with flow (Fig. 1; RM ANOVA: each $p<0.01$, d.f. =1,52). Thus, choice of locomotion direction relative to flow direction can alter the ability of sea stars to move at their fastest speeds.

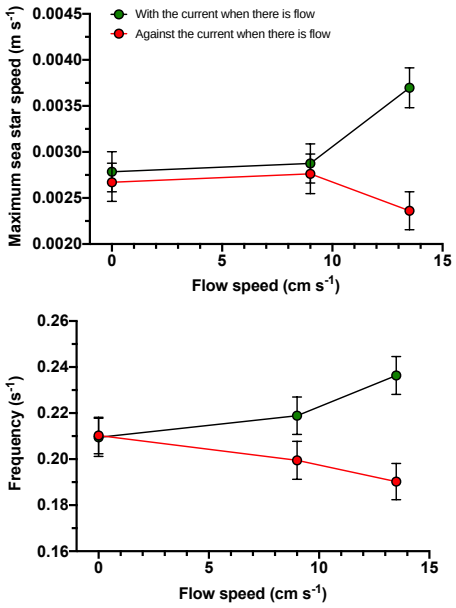

Figure 1: Maximum speed and characteristic frequency of the oscillatory gait of *A. forbesi* for six flow conditions. Symbols represent the mean for all films of all sea stars for a given flow condition. Error bars represent one s.e.

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References

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