Mechanical role of the tube feet in sea star locomotion

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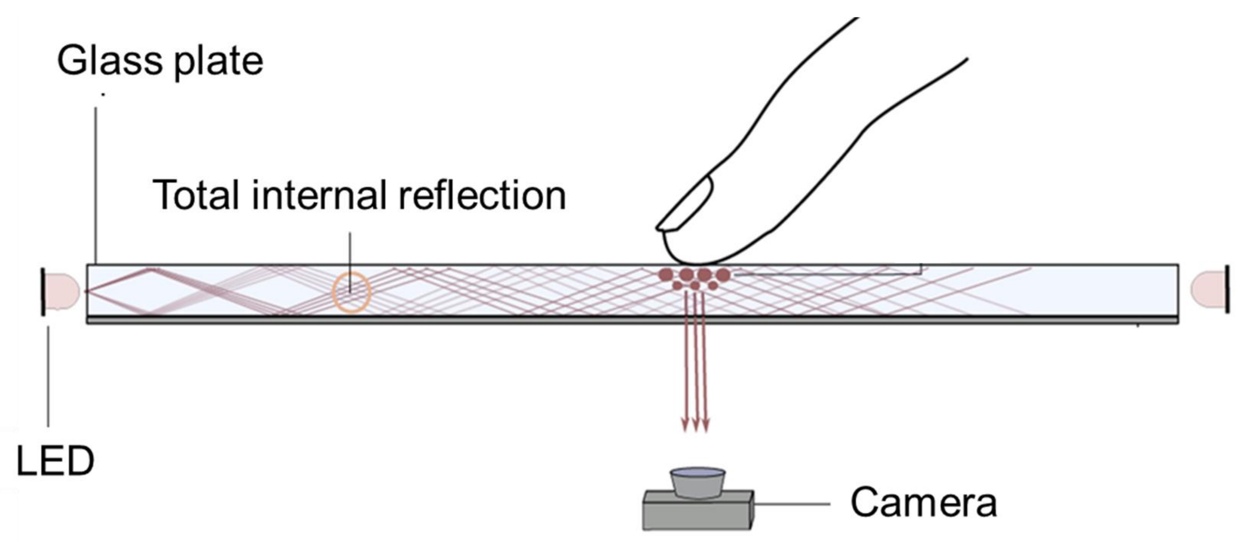
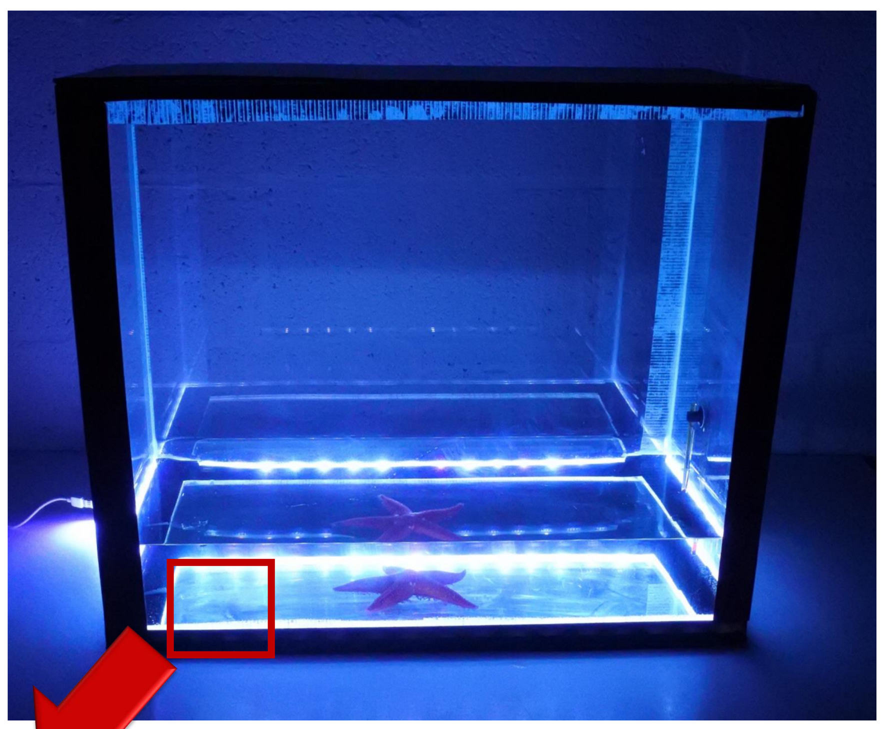
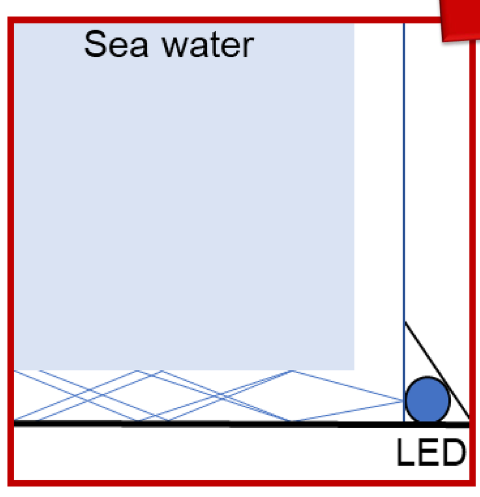
Sea stars use a multitude of small hydraulic organs (i.e., the tube feet or podia), to locomote, to strongly attach to the surrounding, and to pry open the mussels on which they feed. Tube feet are secretory organs in which two types of adhesive cells co-secrete a blend of adhesive proteins to form the adhesive layer joining the tube feet to the substrate (1). Despite the paramount importance of tube feet in sea star locomotion, the regulation of the number of tube feet sticking to a surface during movement is still poorly understood.

Experimental setup

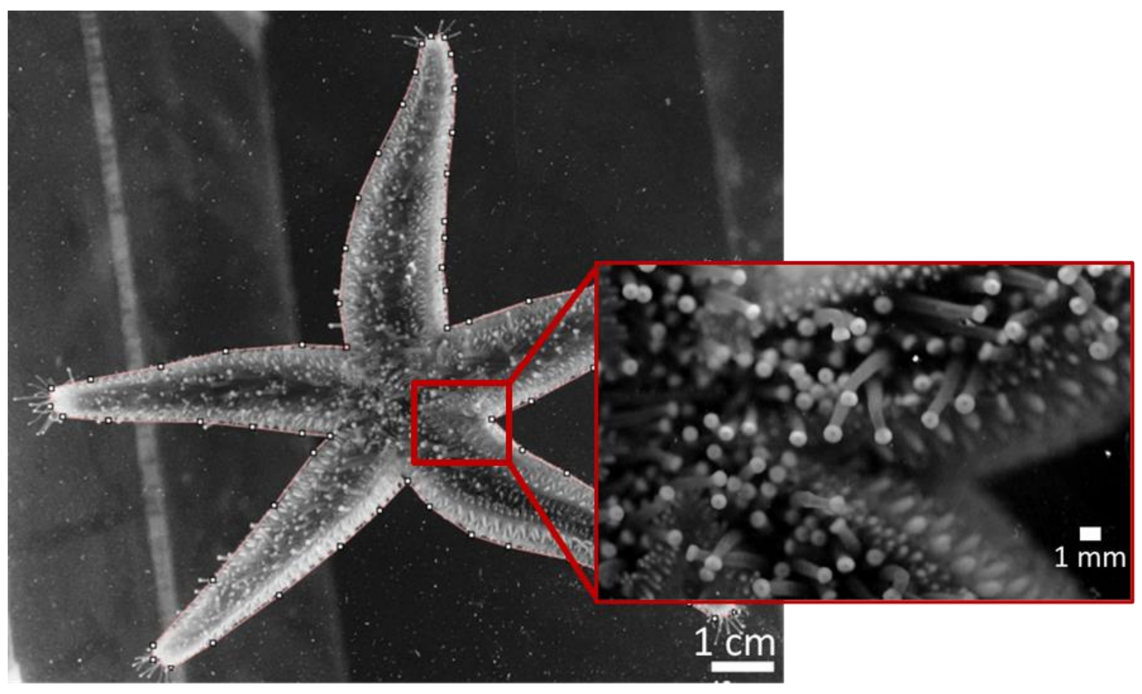


- Schematic of the phenomenon of total internal reflection. The object which comes into contact with a surface provided with the TIRF will diffuse the light and this contact area will be illuminated.



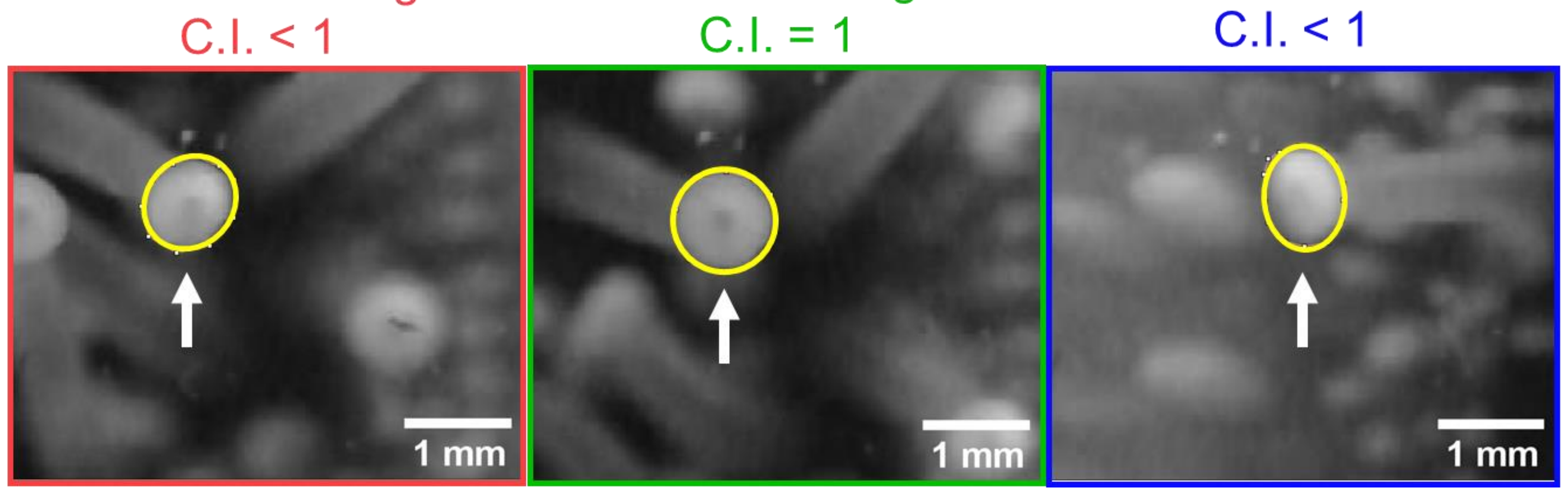


- Experimental aquarium equipped with a total internal reflection (TIRF) system (highlight)



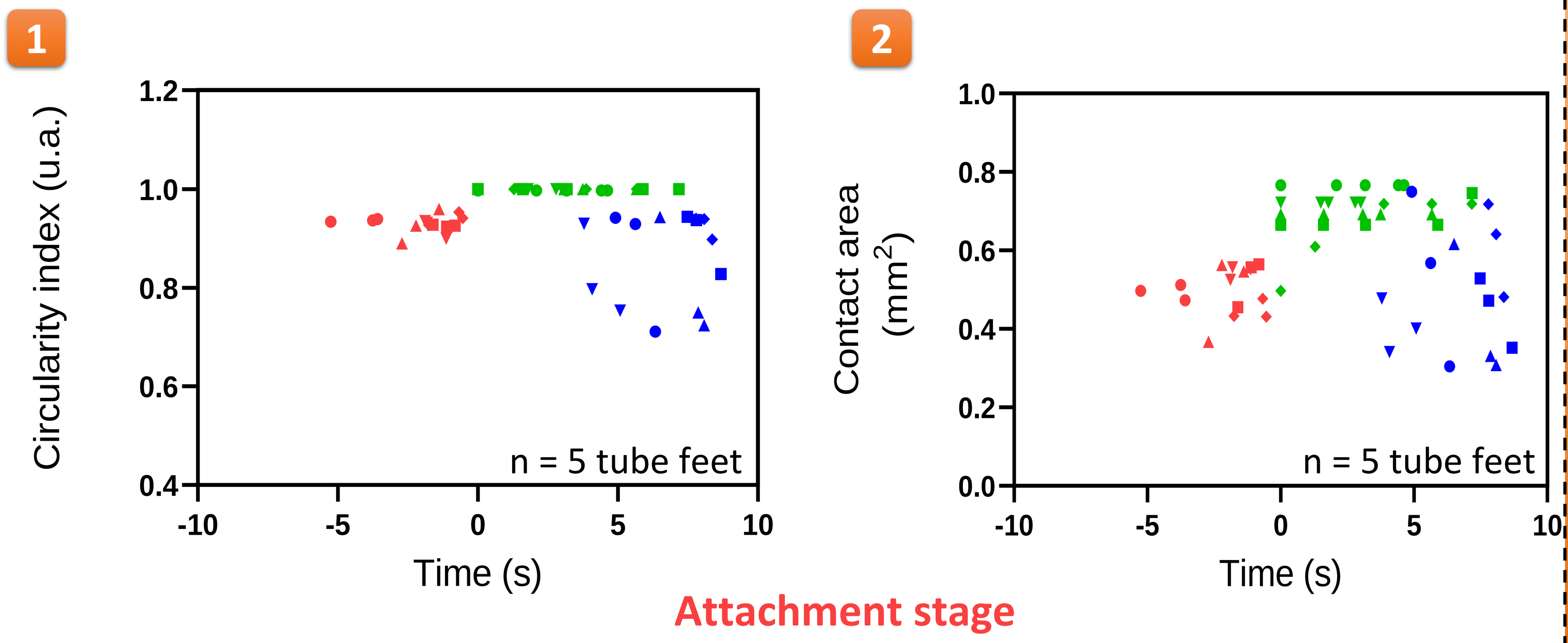
- *Asterias rubens* oral surface is covered with thousand of tube feet (highlight).

Characterization of the adhesion mechanism during locomotion



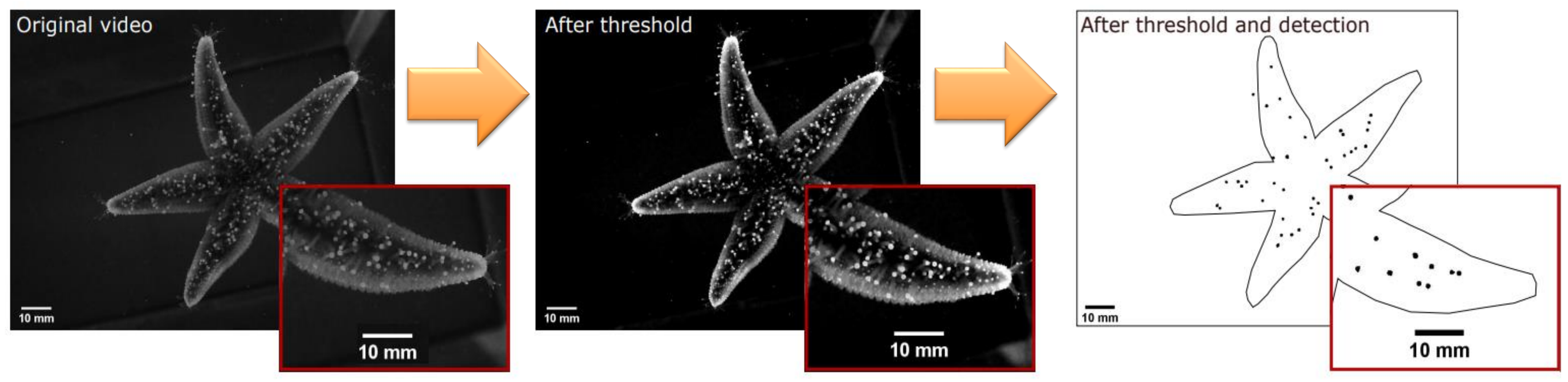
Circularity index (C.I.) = $4\pi \frac{\text{area}}{\text{perimeter}^2}$ $\quad 0 \leq \text{C.I.} \leq 1$

- The three stages of podial adhesion during the movement of the *Asterias rubens* have been demonstrated thanks to videos at high magnification.



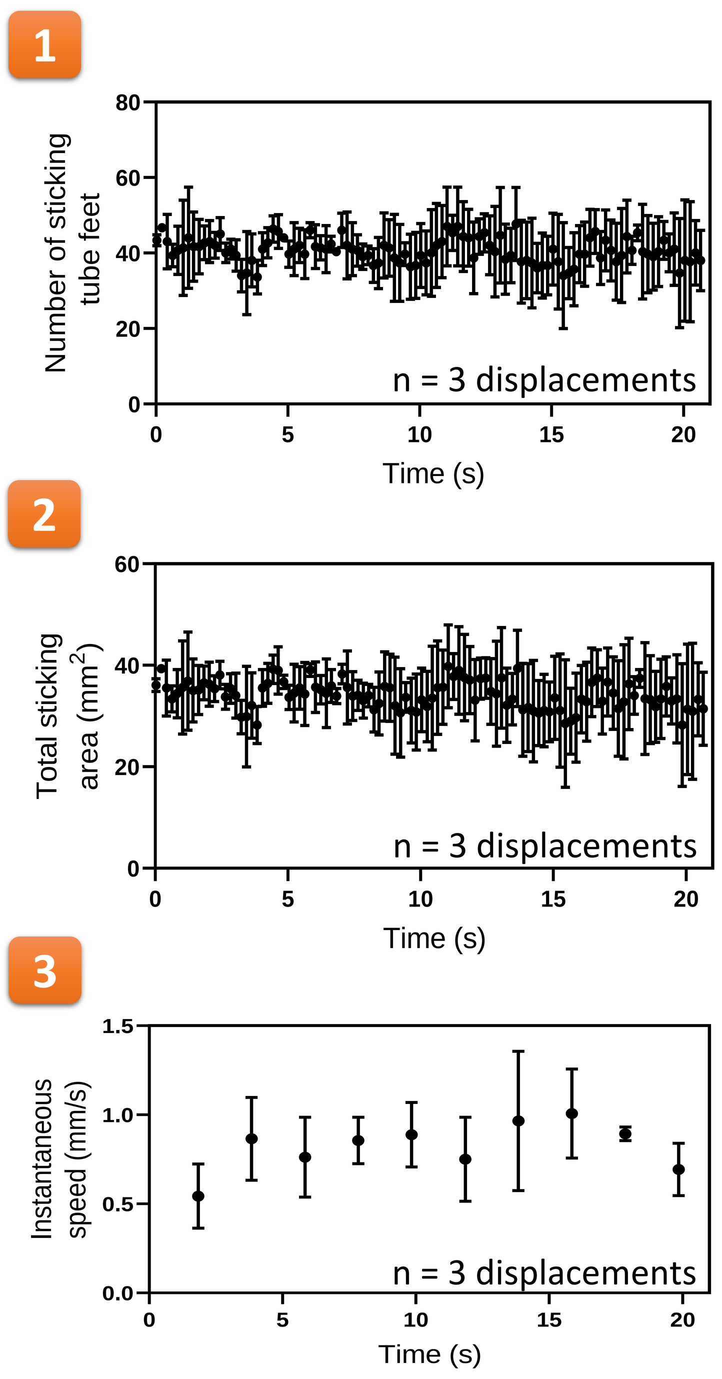
- The variation of the circularity index during the adhesion dynamics (1) shows that during the entire second stage, the adhesion stage, the tube feet circularity index is equal to one = a perfect circle. The variation of the contact area during the adhesion dynamics (2) shows a considerable increase in the area during the attachment stage.

Asterias rubens locomotion



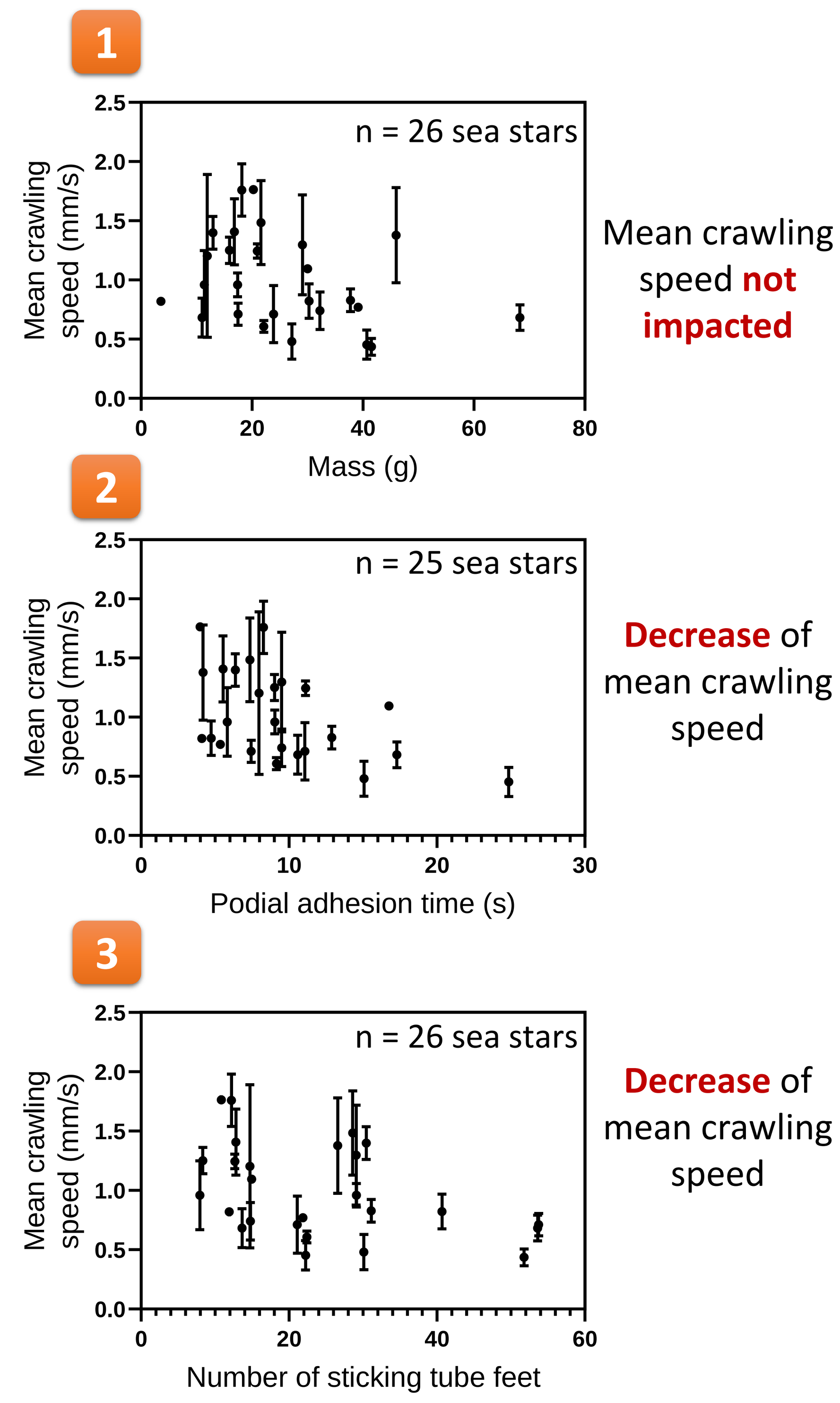
- Image analysis method based on thresholding that we have developed.

Basic locomotion parameters



- Basic locomotion parameters remain **constant** during the locomotion.

Influence of morphological parameters



Conclusion and perspectives

In this project, we developed a robust technique for quantifying the number of tube feet sticking to the substrate during locomotion. Contrary to what is observed in other animals, it seems that the size of *Asterias rubens* has no impact on the mean crawling speed.

A long-term goal for this project is to develop a biomechanical model of sea star locomotion based on the measurement of the adhesion energy exerted by a sea star according to the number of sticking tube feet.

Reference : 1. P. Flammang, A. Michel, A. Van Cauwenberge, H. Alexandre and M. Jangoux, Journal of Experimental Biology, 201, 2383–2395 (1998).

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