Swimming Mechanics of Gossamer Worms

Smithsonian
National Museum of Natural History

MBARI

NSF

Alyssa M. Arington[1,2], Nadege Aoki[1], Ariel A. Harned[1], Natalia Mushegian[1], Kakani Katija[3], Karen Osborn[1,3]

[1]Department of Invertebrate Zoology, Natural Museum of Natural History, Smithsonian Institution, Washington, D. C.
[2]Santa Barbara City College, Santa Barbara, CA
[3]Monterey Bay Aquarium Research Institution, Moss Landing. CA

Introduction:

Gossamer worms are a group of polychaetes that are unique among marine segmented worms. They range in size from a few mm to nearly a meter in length. Unlike most polychaetes, they lack mesenteries that isolate their body segments. They also lack the many bristles at the tips of each of their appendages that polychaetes are named for. These differences make the mechanics behind how they swim particularly interesting because both features typically play a role in polychaete swimming. Tomopterids show remarkable flexibility, maneuverability, and speed in their swimming, contradicting previous hypotheses of the mechanisms of swimming in polychaetes. The purpose of this project is to begin to describe the kinematics of tomopterid swimming.

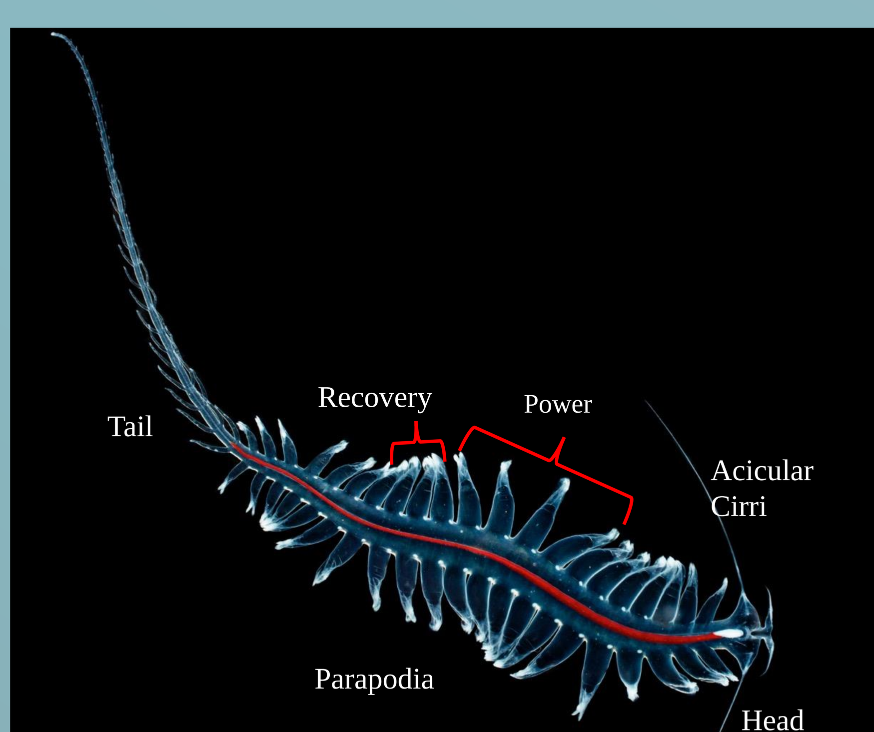

Figure 1. Tomopterids swim using a combination of their paddle-like parapodia (appendages) and a metachronal wave that is generated from the tail. Parapodia stroke from front to back during the power stroke, and are pulled forward during recovery stroke.

Methods:

- Tomopterids collected via remotely operated vehicle *Doc Ricketts*
- High speed videos taken on board the R/V *Western Flyer* with a Photron FASTCAM MiniAX50 high-speed video camera.
- 52 landmarks tracked using MATLAB R2017a and DLT software.
- Counted # wavelengths, # parapodia per wavelength in power and recovery strokes, and # segments per wavelength for 9 animals. Regressions calculated for each in relation to body length.
- Body length, change in parapodia length and displacement of body during wave were calculated from landmarks tracked and compared in power versus recovery portions of stroke.

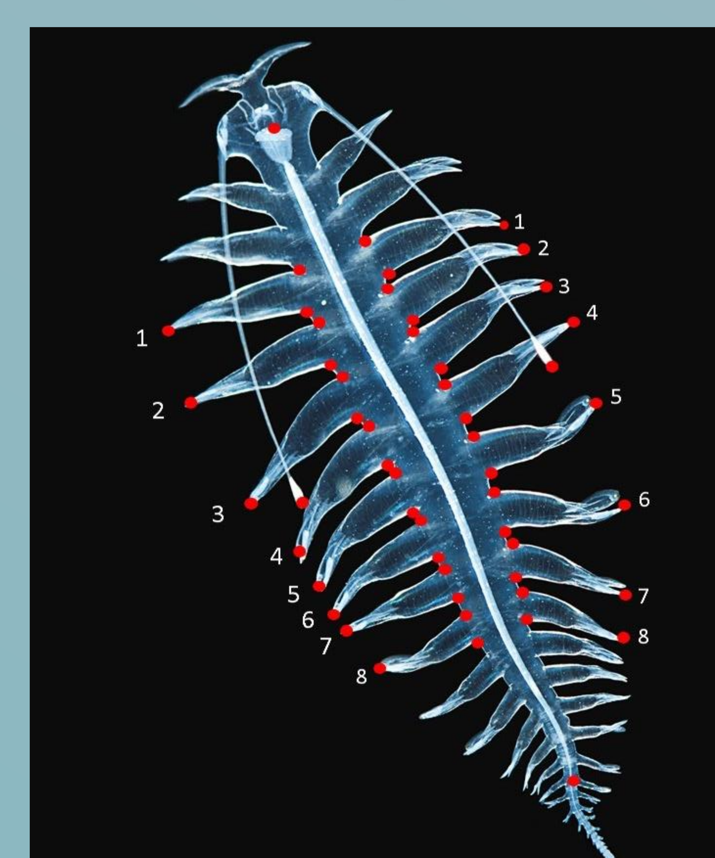

Figure 2. Landmarks tracked using MATLAB.

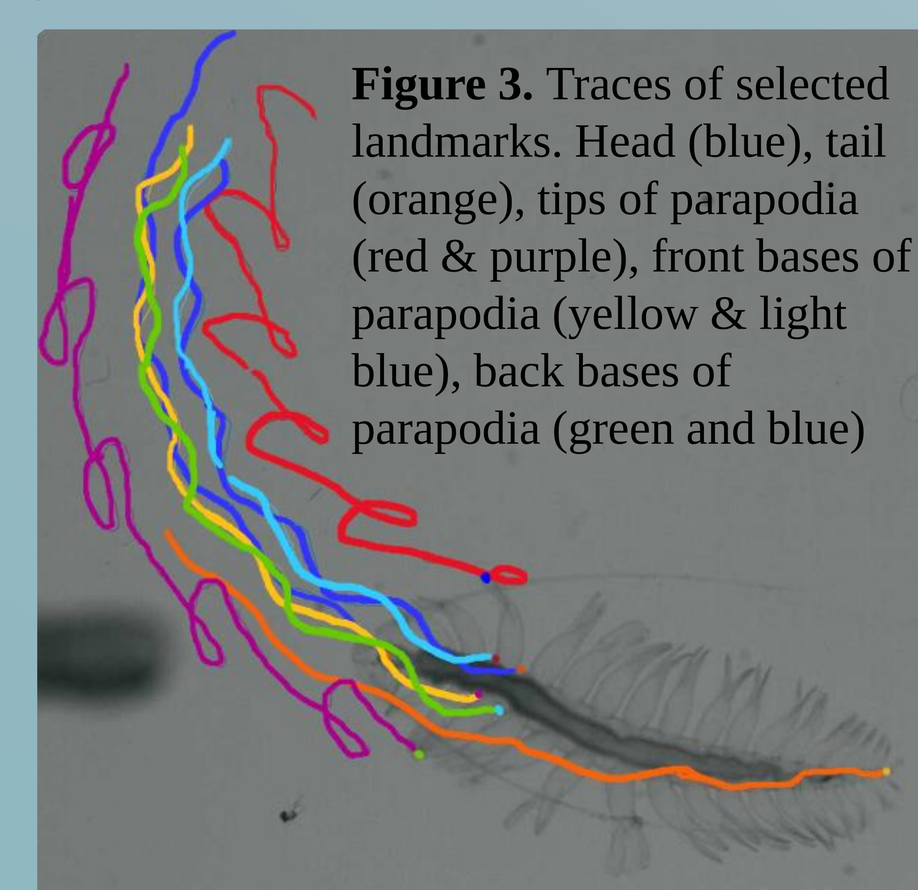

Figure 3. Traces of selected landmarks. Head (blue), tail (orange), tips of parapodia (red & purple), front bases of parapodia (yellow & light blue), back bases of parapodia (green and blue)

Do basic swimming mechanics change with body size?

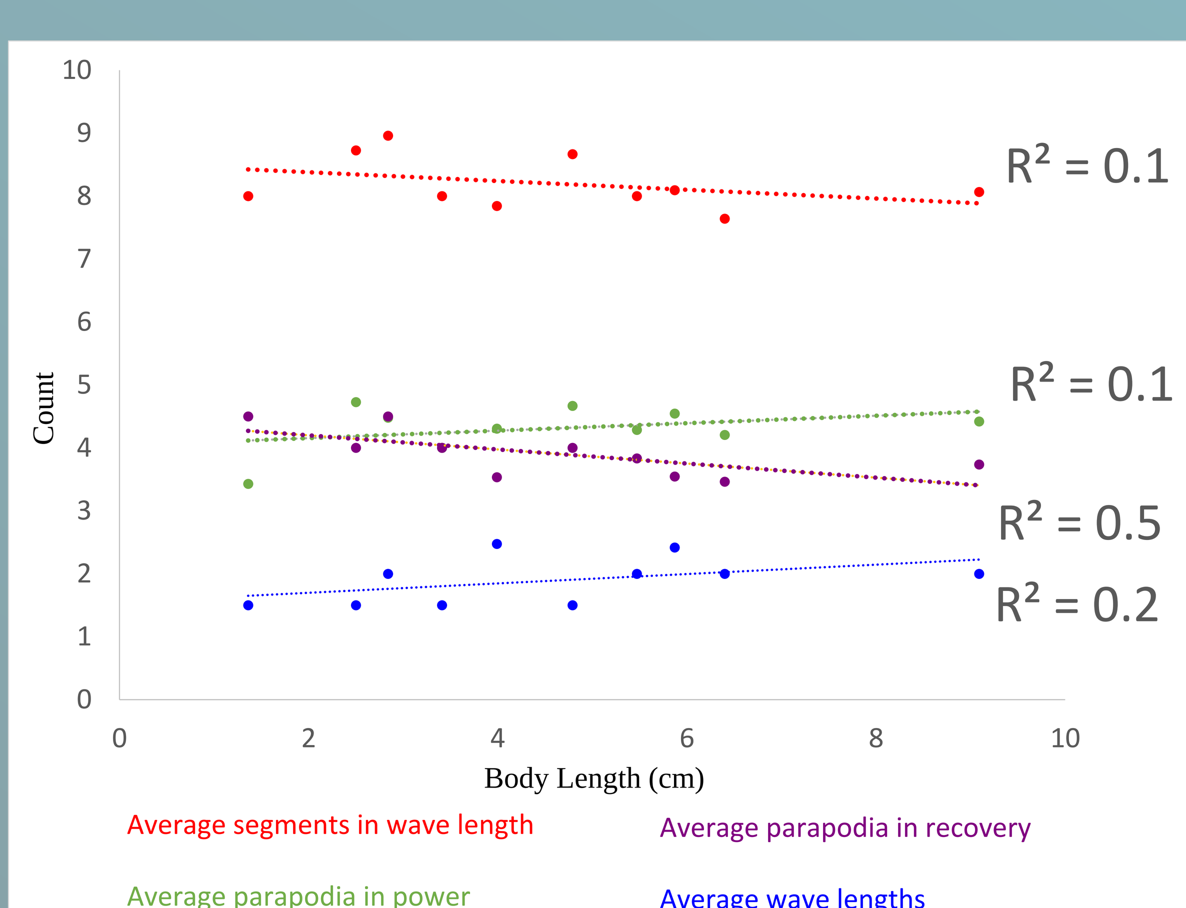

Figure 4. Ten animals, ranging is size from 1.36 to 9.09 cm, were examined. This figure shows four different swimming metrics by body length. None of the trends seen are significant suggesting the basic mechanism used for swimming is not different between different sized animals.

Do the parapodia change in length between power and recovery stroke?

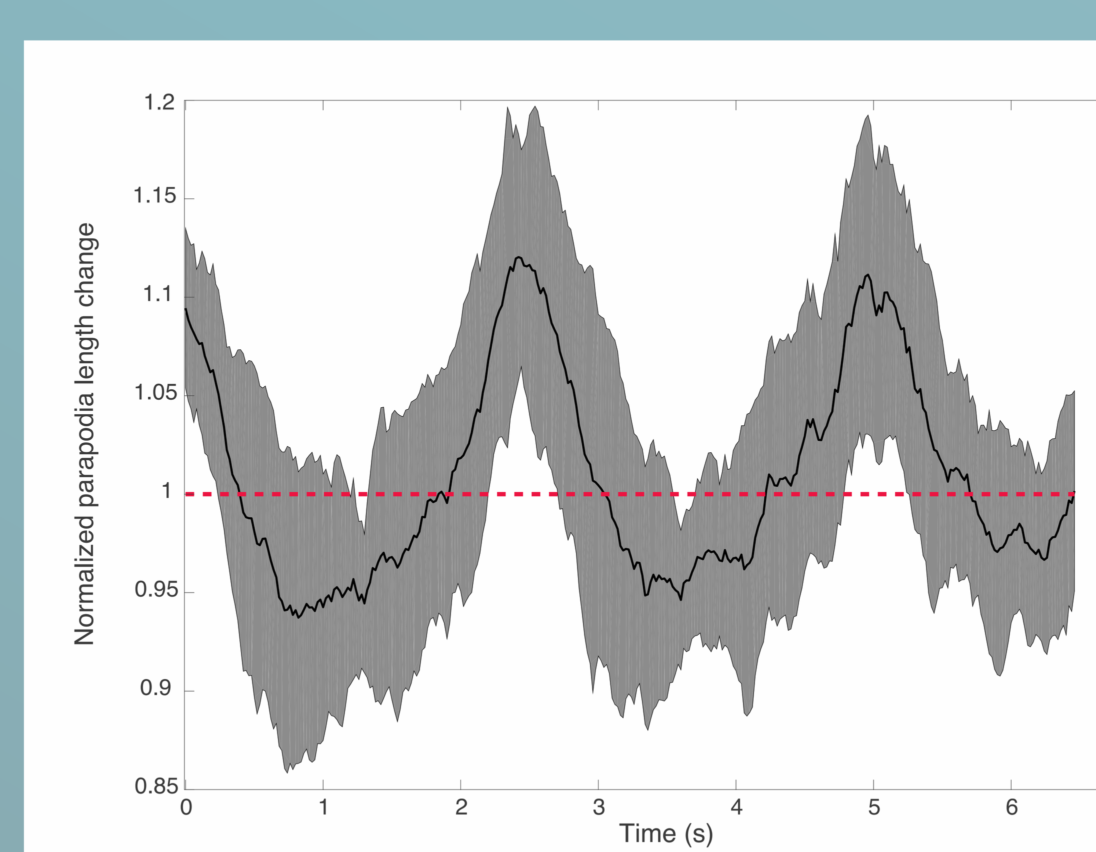

Figure 5. The above figure shows that there is a significant change in parapodia length between power and recovery strokes. This difference in length increases the drag experienced during power stroke and reduces the drag experienced during the recovery stroke.

Does the body wave add to the difference between power and recovery stroke?

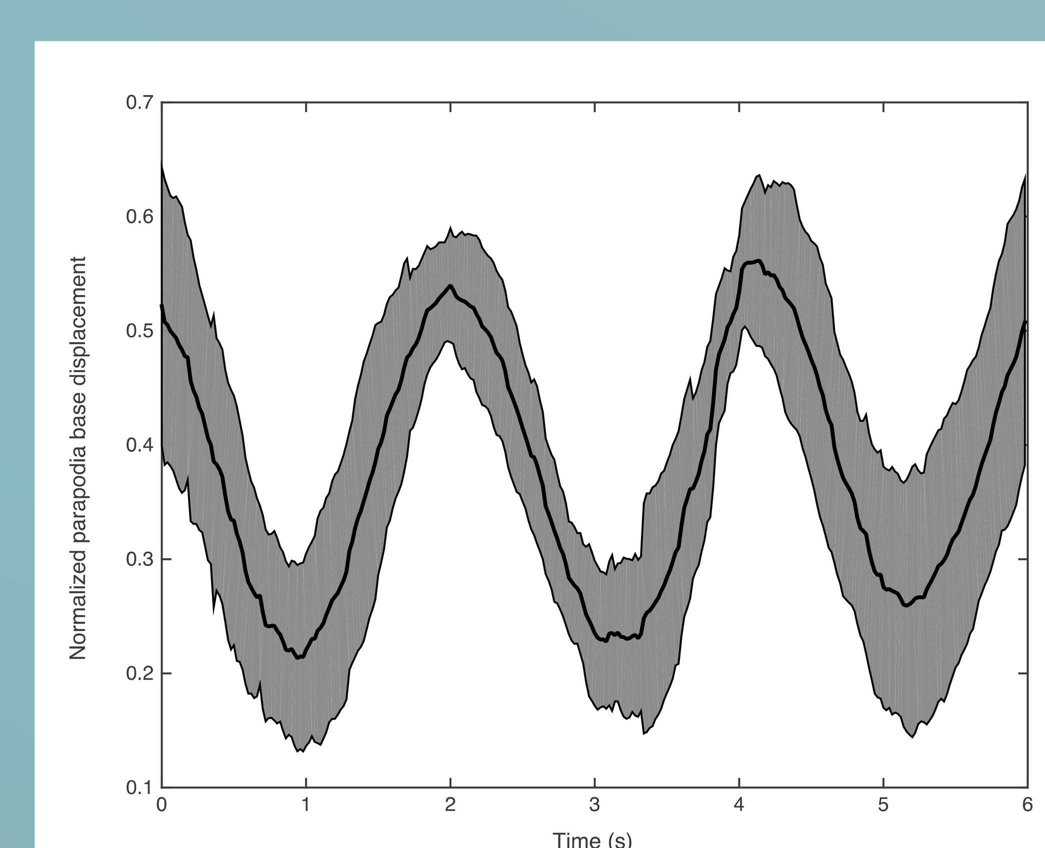

Figure 6. The above figure shows the displacement of the bases of the parapodia created by the body wave. This displacement pushes the parapodia out into water during the power stroke and displaces them in the opposite direction – inward – during the recovery stroke. This further increases the difference in drag between power and recovery stroke.

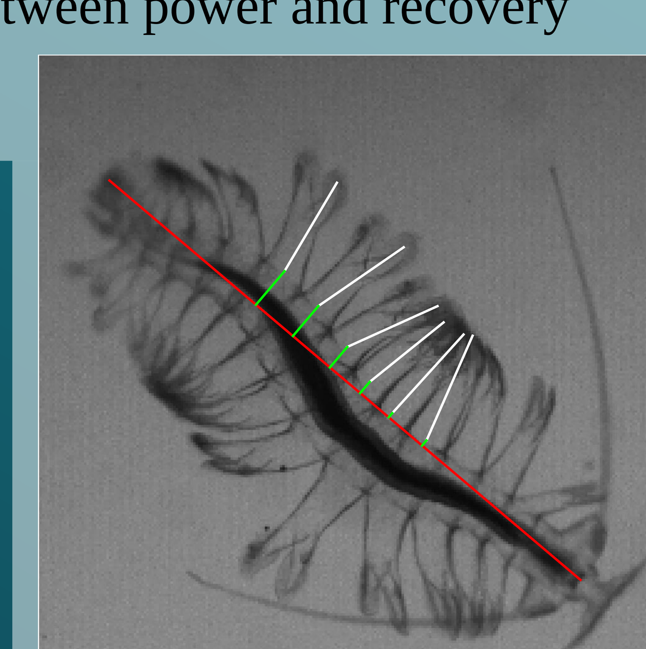

Figure 8. Green line illustrates displacement of parapodia during power vs. recovery

Conclusions:

- Tomopteris swimming mechanics are not significantly affected by animal size.
- Tomopteris changes the length of its apendages to create a difference in drag.
- The body wave further aids in this by displacing the parapodia further in or out.

Acknowlegements:
Funding provided by the National Science Foundation (REU site, EAR – 1560088) and SI-NMNH ADS Small Grant.
We would like to thank Elizabeth Cottrell, Gene Hunt, and Virginia Power, as well as Bruce Robison and the MBARI Midwater lab who made all of this possible.

References:

Clark R.B. and Tritton D.J. Swimming mechanisms in nereidiform polychaetes. J. Zool., Lond. 161:257-271.
Hedrick, T.L. Software techniques for two- and three-dimensional kinematic measurements of biological and biomimetic systems. Bionspiration and Biomimietics. 3(3).
Rouse, G.W. and F. Pleijel. 2001. Polychaetes. Oxford University Press, Oxford (the black book).
Hesselberg T. 2007. Biomimetics and the case of the remarkable ragworm. Naturwissenschaften. 94:613-621.