Investigations of swimming in marine invertebrate larvae

Invertebrate larvae are tiny (< or = 1 mm) and swim rather slowly (0.3 to 2 mm/s) and thus are subject to horizontal currents. However, some larvae can swim vertically and regulate depth under calmer conditions. Published information on larval swimming speeds is based on limited observations at the level of species, ontogenetic stage, and often the larval and experimental conditions at time of measurement are unclear. Projects that examine swimming speed and direction under several, defined conditions in 1 or more species of known stage(s) would help determine how variable speeds can be and address the accuracy of published measurements. This knowledge will provide an updated understanding of swimming by tiny larvae.

The arrangement, number, speed and type of cilia (or appendages operated by muscle) can all impact swimming rates – so studies of swimming need to keep many of these constant to determine the importance of 1 or a few parameters. Nevertheless, larvae swim by moving fluid in their vicinity in a given direction and this may carry them up or down or to a suitable substratum for settlement (see Emlet 1991, 1994; Rebolledo and Emlet 2015).

Nonfeeding larvae of some groups (sponges, bryozoans, tunicate tadpoles) swim relatively rapidly (>1mm/s). Some of these larvae are brooded and able to settle when released from the parent. How does swimming speed change as larvae age and how variable are these species across groups and body size? Many species for study can be obtained locally from the Charleston Marina (see Kelman and Emlet 1999).

Cyprid larvae of barnacles – the final larval stage before settlement – are very fast swimmers by planktonic-world standards. For example, cyprids of *Balanus glandula* swim at 2-4 cm/sec with much faster short burst speeds. A project examining how cyprid swimming speeds vary across species that differ in larval size would help reveal the scaling of size and speed in these saltatory swimmers. In a typical summer the local plankton has 4 species of cyprids that vary in size from 0.5 to over 1mm in body length. Some species may also be raised in the laboratory (see Lamont and Emlet 2021).

These project ideas or others on larval swimming involve considerable amounts of microscope work to obtain larvae from plankton samples and possibly to collect images of swimming larvae. Projects also require recording and analyzing videos of swimming larvae which can take a long time. My approach is direct observation/recoding and simple measurements aided by computer programs. Interns with strong computational skills might be able to facilitate data collection, but basic understanding of computers using excel and Image-J (FIJI) will also get the data collected and analyzed.

Cited References and others studies on swimming from my laboratory:

Lamont, E.I. and **R.B. Emlet**. 2021. Swimming kinematics of cyprids of the barnacle *Balanus glandula*. Integrative and Comparative Biology.

Rebolledo, A.P. and **R.B. Emlet** 2015. The parachute function of the hull in the eggs of *Mopalia kennerleyi* (Chitonida: Mopaliidae) and swimming of its larvae through ontogeny. Invertebrate Biology 134(1): 31-37. doi: 10.1111/ivb.12076

Kelman, D. and **R.B. Emlet** 1999. Swimming and buoyancy in ontogenetic stages of the cushion star *Pteraster tesselatus* (Echinodermata: Asteroidea) and their implications for distribution and movement. Biological Bulletin 197: 309-314.

Emlet, R.B. 1994. Body form and ciliation in nonfeeding larvae of echinoderms: functional solutions to swimming in the plankton? American Zoologist 34: 570-585.

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Emlet, R.B. 1991. Functional constraints on the evolution of larval forms of marine invertebrates: experimental and comparative evidence. American Zoologist 31: 707-725.