DEVELOPMENT OF COPEPOD ESCAPE BEHAVIORS IN RESPONSE TO A HYDRODYNAMIC STIMULUS

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ABSTRACT

The success of any species hinges on the survival of the early life stages. In many planktonic organisms, including the calanoid copepods, these early life stages are heavily preyed upon and thus often sustain high rates of mortality. In order to better understand the predator-prey interactions in the early developmental stages of copepods, I investigated the normal swimming and escape behaviors of nauplii and early copepodites of two abundance and widespread estuarine calanoids. High speed 3-dimensional microcinematography was used to study these behaviors in *Eurytemora affinis* and *Parvocalanus crassirostris*. Escape behaviors were elicited using a brief hydrodynamic stimulus produced by a dipole. Normal behaviors were classified by the presence or absence of motion of the appendages. Durations of each period, motion or non-motion, were measured along with the distance traveled. Net movement over several periods was also calculated for each organism. Species-specific behaviors in the periodicity and frequency of jumps during normal swimming were observed. Although both species exhibited swim-sink behavior, *P. crassirostris* nauplii were consistently less active than *E. affinis*. These differences continued to be visible as the copepod grew from nauplius to copepodite. Normal swimming speeds scaled negatively with body length, from 20 to 2 BL s^{-1} between early nauplius and late copepodite stages in both species. The normal behavior of the adult male stage of *P. crassirostris* did not follow the scaling, but did adhere to predicted values for non-feeding males. Reynolds (Re) numbers of normal swimming speeds were different between the species, all less than 0.5 in *P. crassirostris* and greater than 1 in copepodites of *E.affinis*, and revealed a gradient in levels of viscosity experienced by the two copepods.

Escape behaviors were categorized into four responses following the presentation of the stimulus: escape jump(s), escape jump(s) followed by freezing of all appendage movement, immediate freezing of all appendage movement, or no change in behavior. The time between the stimulus presentation and escape jumps was measured, as well as the time to the achievement of maximum velocity and the number of power strokes during the escapes. Duration, distance, maximum and average velocity, and acceleration were calculated from three dimensional coordinates of escape jump tracks. Despite being smaller in size, *P. crassirostris* escaped further and longer than *E. affinis* in the developmental stages; the greatest jumps recorded were over 3mm in length and lasted nearly 200 ms. Over the development of both species, however, jump lengths and durations of *E. affinis* increased and surpassed those of *P. crassirostris*. A scaling of increasing escape speeds with body length was found in both, a trend that has been seen in the escape speeds of many organisms. Escape speed Reynolds numbers were all greater than 1 in *P. crassirostris* and greater than 10 in *E. affinis*, spanning over two orders of magnitude through the development of both species. All stages of both species maintained maximum speeds between 200 and 500 BL s^{-1}, despite a gradient of forces, as evidenced by the continuum of Re numbers of escapes.