EFFECT OF VORTEX STIRRING ON FERTILIZATION EFFICIENCY IN MARINE INVERTEBRATES

JILLIAN R. HARTFORD* AND JOHN P. CRIMALDI

Department of Civil and Environmental Engineering
University of Colorado
Boulder, CO 80309, USA
* Jillian.Hartford@colorado.edu

Various benthic invertebrates (e.g. sea urchins, anemones, corals) rely on broadcast spawning, a fertilization strategy whereby male and female adults simultaneously release sperm and egg into the surrounding flow [1]. In order for the fertilization reaction to occur, the two scalars, sperm and egg (gametes), are brought together via turbulent stirring, molecular diffusion, and sperm taxis. The combined effect of instantaneous turbulent stirring and mixing is often modeled using an eddy diffusivity [2]. Due to the strong time-average turbulent dilution of the gametes, this approach significantly under-predicts fertilization rates recorded in the field [3-4]. We hypothesize that the instantaneous turbulent stirring and mixing processes, which are not captured by the eddy diffusivity approach, yield higher fertilization rates.

Several numerical modeling approaches are used to investigate the role of turbulent stirring processes on fertilization efficiency. A particle-tracking model is used in combination with various types of vortex flows to explore how stirring and mixing processes influence the fate and distribution of two initially distinct gamete sets. The subsequent fertilization rate depends on the product of co-occurring egg and sperm concentrations [5]. Therefore, the gametes are treated as reactive species and gamete coalescence is reflected through an effective mass removal within the system.

The results of this study suggest that instantaneous turbulent processes produce significantly higher fertilization relative to time-averaged models. Furthermore, the results indicate that vortex structure imposes spatial correlation on initially non-overlapping gamete sets, which increases potential fertilization rates. Collectively the models show that fertilization enhancement is primarily dependent on the Peclet number and is robust to the initial placement of the gametes. Both the single vortex and multiple vortex models provide insight into the physical mechanisms that enhance fertilization.

References

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