Predicting the effects of climate change on the fertility and reproduction of marine invertebrates

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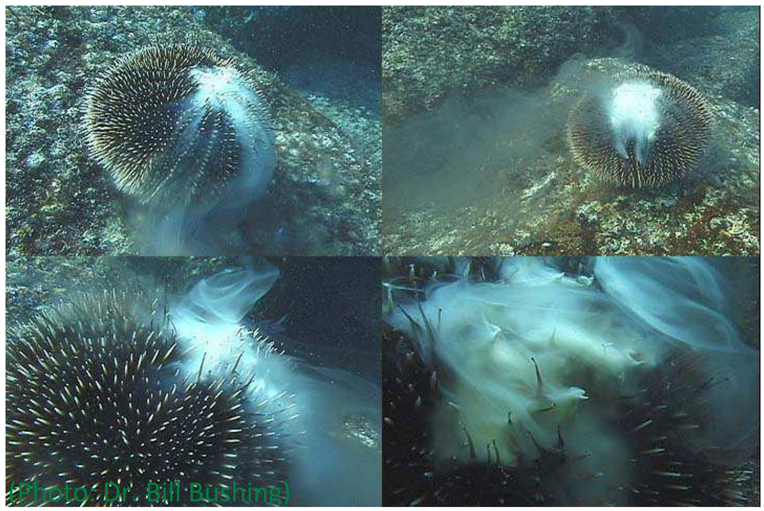
Introduction: The release of CO_2 into the atmosphere by humans is causing broad-scale changes in marine ecosystems. Water temperatures are increasing around the world, and the direct uptake of CO_2 into seawater is causing oceans to become more acidic. Understanding the impacts of this environmental change is one of the most important issues facing marine biologists today. Climate change is particularly detrimental to marine invertebrates, a diverse group of species (*e.g.*, sea urchins, corals, clams) that are often keystones in their ecosystems. In broadcast spawners (*i.e.*, species that release sperm and eggs directly into the water where the gametes meet and fertilization takes place), environmental change can disrupt gamete function (*e.g.*, by reducing sperm swimming speed). This may lead to massive reproductive failures that threaten species and ecosystems. Yet, despite the growing body of empirical work that has studied the effects of environmental change on broadcast spawning species, the field has remained largely atheoretical. As a result, we currently lack a clear mathematical basis for understanding how climate change will impact fertility and reproduction in marine invertebrates.


(Photo: Dr. Bill Bushing)

A male sea urchin releases sperm into the water.

Project Summary: While we know how environmental change affects the physiology and behaviour of gametes, we have no theoretical model to predict how changes in gamete function will interact with changes in adult spawning density or in the timing of gamete release to affect the reproductive success of broadcast spawners. Moreover, we have no formal mechanism to predict how changes in reproductive rates in broadcast spawners will impact species persistence or ecosystem stability. The student in this project will expand the theory of fertilization kinetics in broadcast spawning species, and will apply that theory to predict how anthropogenic environmental change will affect 1) broadcast spawning fertilization success, 2) population persistence in broadcast spawners, and 3) the evolution of gamete traits in changing marine environments. By addressing these issues, we can help ecosystem managers decide which species to monitor and when to intervene to protect vulnerable species from local or global extinction.

The student will develop an expertise in three complementary research approaches. 1) *Mean field theory:* The success of broadcast spawning depends on encounters between individual sperm and egg cells. The mean field approach will allow the student to reduce this multi-body problem to simple system of differential equations. The problem can then be treated analytically to make general predictions about the effects of environmental change on broadcast spawners. 2) *Individual based models*: Mean field approaches ignore stochasticity in encounter rates. Stochasticity may be important in systems or areas where gamete density has been reduced. Spatially explicit individual-based models will allow the student to test the predictions of analytical models *in silico*. 3) *Experimental testing*: The predictions generated by mathematical models are in essence hypotheses, and hypotheses must be tested. Predictions will be tested empirically by examining the impacts of climate change on sperm performance and fertilization success in common and ecologically important UK marine invertebrate species that are sensitive to environmental change (*e.g.*, sea urchin and clam species). A student with strong quantitative skills and a background in biology, mathematics, computer science or physics would be well-suited to this project.

References

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