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Finding the Chemical Signals that Induce Marine Larvae to Settle to the Sea Floor

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Background

Many benthic marine animals begin life as free-floating larvae, drifting high above the ocean floor. A number of these, after feeding on algae, descend to the ocean bottom, where they complete their metamorphoses into miniature versions of their adult forms. These barnacles, clams, oysters and starfishes will spend the rest of their lives on the seafloor, never again being as mobile as they were as larvae. For this reason, perhaps the most important event of their lives is settling onto prime rock substrate.

Up until recently, the common wisdom among scientists was that larvae are passive drifters, tossed at the whim of powerful waves and currents. Where they settled was believed to be a matter of random chance. This theory had holes, however, since field observations consistently showed that settlement rates are higher on preferred reef materials.

In this project, a scientist shows that marine larvae, far from being mere floats, are almost acrobatic in their maneuvers to land on prime substrate, and therefore are much less at the mercy of fate than previously imagined.

Certain chemicals released from the seafloor are now believed to induce larvae to descend. That is, larvae can "sniff" chemicals in seawater—even very dilute amounts. These chemicals, called settlement inducers, help explain observations of larvae clusters on preferred substrates.

The Project

California Sea Grant funded Dr. Richard Zimmer of the University of California at Los Angeles to identify settlement inducer compounds in larvae of the California red abalone and Eastern oyster—high-value shellfish whose wild populations are at, or near, their historical lows.

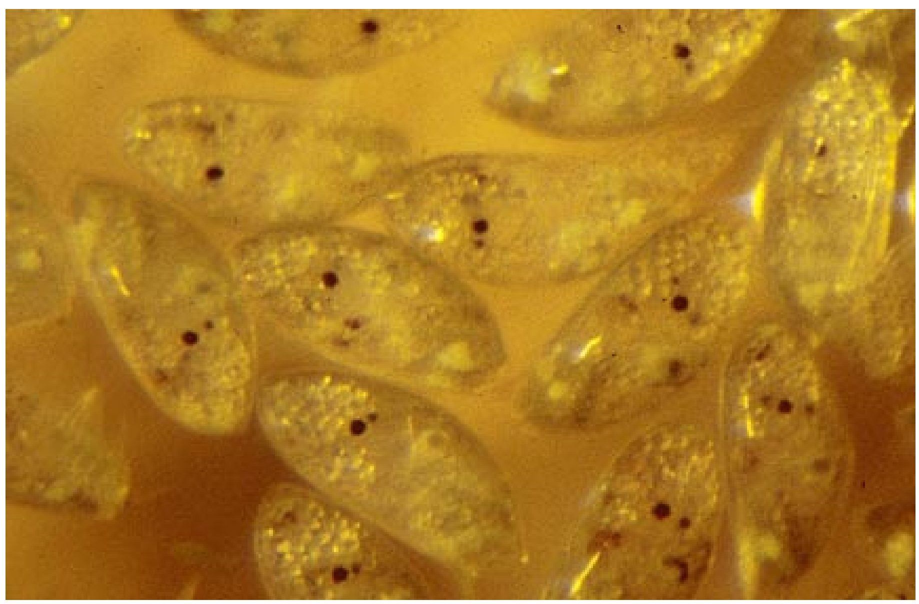
Method

Using a number of molecular techniques, including hollow fiber dialysis and liquid chromatography, Dr. Zimmer and colleagues were able to characterize these compounds in oyster larvae.

In a subsequent analysis, oyster larvae were shown to respond to low molecular weight peptides (proteins), which have the amino acid arginine at the carboxy-terminus. In field experiments, the same compounds were shown to attract barnacle larvae as well.

Dr. Patrick Krug, a postdoctoral researcher working with Dr. Zimmer, described the chemical signals as "akin to someone smelling cookies baking and wanting to stay in the kitchen."

In further experiments, the researchers made synthetic versions of the inducer compounds, predicted from computer models to be among the most powerful attractants. They found that the most powerful agent for inducing larval settlement was a chemical called GGR (glycyl-glycyl-L-arginine), which mimics the cues released by adult oyster reefs in nature. To verify the attracting power of GGR and the other synthetic molecules, the scientists tested 53 different compounds on live oyster larvae. They then used another set of computer models to develop a gel that releases GGR at the same rate as real oyster beds. This gel was placed in collecting trays to test GGRs



Barnacle larvae do not merely drift with ocean currents. By waving their cilia, they can issue a controlled descent onto perferred bottom habitats. Sea Grant research has shown that their descent is triggered by chemical cues from rock reefs. Photo: UCLA.

attracting power in laboratory and controlled field experiments.

In laboratory experiments, larvae were observed to position themselves near the GGR source. Dr. Zimmer said, "They dive bomb downwards by moving their little bands of cilia—little hairy whips on their exterior. They can coordinate their cilia and go where they want. It is pretty amazing for being so small. They are only about one-hundredth of an inch long."

In the field, scientists learned another amazing fact: the GGR gel attracts not only oyster but also barnacle larvae. Zimmer said, "They (the barnacles) settled like crazy." Settlement rates were enhanced about tenfold.

Dr. Zimmer's experiments are the first to show that larvae can settle in response to waterborne chemical cues under natural flow conditions.

For red abalone, the researchers were unable to identify natural, waterborne settlement inducers, so they changed their focus to investigate the chemical signals that enhance fertilization of male and female gametes. These experiments showed that red abalone eggs release a chemical that helps sperm navigate—and spurs them to swim faster near an egg. This chemical has been isolated and partially characterized through nuclear magnetic resonance studies.

Zimmer said of the compound: "What is so exciting is that the molecular structure of the attractant is remarkably similar to that of the mammalian neurotransmitter, serotonin. There may be strong homology between the receptor systems that modulate activity in the brain of a mammal and that operate the attraction of sperm and egg in an animal like red abalone. It appears that certain features of chemical recognition systems have been widely conserved throughout evolution."

Their abalone work also has implications for management of this highly depleted, once valuable, fishery. Dr. Krug said, "For red abalone, the bottleneck in their recovery may not be about larval settlement and finding the right bottom habitat. It is likely that the density of gametes is too low to ensure fertilization."

Applications

Inducer compounds can be used to promote colonization of certain habitats by commercially and ecologically valuable marine organisms. In theory, knowledge of the molecular structures of these compounds may be used in reverse to develop compounds that repel unwanted larvae, such as barnacle larvae that colonize boat hulls.

Cooperating Organizations

Bodega Marine Laboratory
California Department of Fish and Game
Cultured Abalone, Inc.
Los Angeles County Wastewater Management Treatment Plant
The Abalone Farm
Virginia Institute of Marine Science

Publications

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