

Research Horizons

Winter 2003

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Signals in the Sea

Researchers probe the ocean depths to learn how plants and animals communicate using chemical signals.

By Jane M. Sanders

PERHAPS THE HARDEST PLACE in the world to be a plant is also the best place for many species. In shallow-water coral reefs, plant-eating fish bite into marine vegetation up to 150,000 times per square meter every day.

courtesy of Mark Hay

"You could throw in bundles of seaweed, and they wouldn't hit the bottom," says Mark Hay, a professor of biology at the Georgia Institute of Technology. "It's like throwing meat to piranhas. Yet some aquatic plants grow better there than elsewhere."

How is this possible? Studies in aquatic chemical ecology at Georgia Tech and elsewhere show that marine plants – and animals – have adapted to their predator-rich environments by using chemical defenses. And not only do chemical signals drive

predator/prey interactions, they also affect such critical processes as mating and habitat choice, Hay says. Also, they produce a cascade of indirect effects that change population structure, community organization and ecosystem function.

Research is yielding fascinating examples of chemical signaling among aquatic species. Some coral reef plants, for instance, produce multiple toxins to keep from being eaten by fish. Meanwhile, certain sea slugs and shrimp-like crustaceans called amphipods selectively feed and live on poisonous plants. By doing so, they escape from, or make themselves repulsive to,

Ga. Dept. of Industry, Trade & Tourism predators.



[\(300-dpi JPEG version - 856k\)](#)



NOAA



Researchers at Georgia Tech – in collaboration with their colleagues at the Skidaway Institute of Oceanography and the Scripps Institution of Oceanography – work in a variety of marine environments, including coral reefs, deep sea vents, mangroves, tidal rivers and marshes, mud flats and open oceans.

In the mating realm, microcrustaceans called copepods overcome limited vision and the vastness and viscosity of the ocean to find a partner. Females emit a trail of mating chemicals encased in a tunnel-like structure that males can sense and follow.

And when it comes to habitat choice, blue crabs may select a sandy, smooth tidal channel instead of a turbulent oyster reef because they have learned they can more easily detect the chemical odors of their prey when those smells are not mixed by rough waters.

Intrigued by the fundamental scientific discoveries, as well as the potential applications in bioremediation and biologically based device design, Georgia Tech began a significant research program in aquatic chemical signaling in 1999. With several substantial grants from the National Science Foundation and additional funds from government and private sources, the program now boasts an experienced team of interdisciplinary researchers and a unique graduate education curriculum open to biology, chemistry and environmental engineering students. (See sidebar titled [The Broad Side](#).)

"We have a group that can determine how water moves, how chemical signals are dispersed in that water, how animals perceive and respond to those signals, specific chemicals used for these signals, and how all of these factors combine to affect the ecology and evolution of marine and freshwater systems," says Hay, who heads the research and graduate education programs in aquatic chemical signaling.

Researchers at Georgia Tech – in collaboration with their colleagues at the [Skidaway Institute of Oceanography](#) in coastal Georgia and the [Scripps Institution of Oceanography](#) in La Jolla, Calif. – work in a variety of marine environments, including coral reefs, deep-sea vents, mangroves, tidal rivers and marshes, mud flats and open oceans.

"We want to understand the chemical mechanisms involved in organism interactions in aquatic systems," Hay explains. "By understanding those mechanisms, we can more deeply understand the evolution and biology of marine systems in general."

That knowledge can be applied to:
 environmental management and conservation;
 remediation of contaminated ecosystems;
 human health issues; pharmaceutical discovery
 and development; aquaculture; and the design



of devices such as chemical-sensing robots.

"We are somewhat like biomedical researchers of decades ago," Hay says. "They discovered that bread mold produced antibiotics, and by applying small amounts of this to humans, they could cure harmful diseases and infections. We differ from these early researchers in that we are studying the health and function of entire ecosystems, rather than that of individual species like humans.

courtesy of NOAA



Certain sea slugs, such as the sea goddess shown here, and shrimp-like crustaceans called amphipods selectively feed and live on poisonous plants. By doing so, they escape from, or make themselves repulsive to, predators.

Georgia Tech students and faculty led by Professor Mark Hay, center, conduct aquatic chemical signaling research with their colleagues at the Skidaway Institute of Oceanography on the coast of Georgia. ([300-dpi JPEG version - 596k](#))

"But we are similar in that we are seeking to understand how small chemical signals can produce large results, and how humans might use this understanding to rehabilitate entire ecosystems. We hope to discover basic chemical and ecological interactions that point to biological fulcrum points, where modest intervention by humans can have large positive effects on ecosystem health and function."

He adds: "We may be entering a time in Earth's history where simply 'conserving' nature will not be enough. Some ecosystems have been so fundamentally altered that they may not recover without humans intervening to fix them – much like an auto mechanic fixes a car. The good mechanics fix the specific problem and get you back on the road. The bad ones change lots of parts, give you a tune-up and still don't fix the problem. We want to make Georgia Tech students into ecosystem mechanics who fix problems quickly, efficiently, and with minimal intervention and expense."

This will often require interdisciplinary collaboration, and that kind of interaction is a strength of Georgia Tech's research program, Hay says.

For example, [School of Biology](#) Professor Jeannette Yen collaborates with organic chemist Julia Kubanek, an assistant professor in the School of Biology, to identify and characterize chemicals emitted by female copepods in search of mates. She also consults with fluid mechanist Don Webster, an assistant professor in the [School of Civil and Environmental Engineering](#), to simulate the turbulent flow environment in which copepods live.

"You can look at the chemistry of an animal, but you need to know the biology, too," Yen says. "And you need to know the physics to understand the flow and the communication channel."

Microbiologist Frank Loeffler, an assistant professor of environmental engineering, has built his career on interdisciplinary collaboration. "I bring my expertise to environmental engineering

photo by Stanley Leary



Georgia Tech students and faculty conduct aquatic chemical signaling research with their colleagues at the Skidaway Institute of Oceanography. ([300-dpi JPEG version - 604k](#))

research," he explains. "I'm sort of a bridge between basic scientific discovery and applied engineering solutions."

Collaboration, such as this, between disciplines is critical to future scientific discovery and technological development, Loeffler says.

courtesy of John Parker



Blue crabs may select a sandy, smooth tidal channel instead of a turbulent oyster reef because they have learned they can more easily detect the chemical odors of their prey when those smells are not mixed by rough waters. ([300-dpi JPEG version - 371k](#))

"Progress is made at the interface between disciplines or between the knowledge of different people," he adds. "I know my stuff pretty well, but to go to the next step, I need to connect with other disciplines. If we come together, there will be new scientific discoveries, and that's what science is all about."

With so much excitement within the aquatic chemical signaling research team at Georgia Tech, Hay is hoping to share the group's enthusiasm with the general public. He is involved with research, conservation and environmental education plans for the Georgia Aquarium, which will be built in Atlanta near the Georgia Tech campus. Programs

and exhibits at the aquarium will provide an opportunity for researchers to share some of their findings with the public, Hay says.

"We want people to understand that organisms are driven by chemical signals," he notes. "People follow chemical signals, too, but we don't realize when we do.... Also, it's important to note that marine and terrestrial systems are interconnected. There are many complex cascades of indirect interactions between them."

Assistant Professor Julia Kubanek also sees the aquarium as an opportunity to explain why researchers are investigating chemical signaling.

"The public often sees researchers asking seemingly esoteric questions and wonders why anyone cares," Kubanek says. To the applications Hay mentioned, she adds two more reasons:

- (1) Studies of interactions between animals and plants could teach humans a lot about themselves. Scientists often find biological and behavioral analogies between lower and higher organisms.
- (2) Much research has an economic or human health connection. Kubanek cites her study of chemically mediated interactions between phytoplankton and zooplankton. It could shed light on how to stop toxic algae blooms that can beach whales and kill fish.

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Last updated: April 12, 2003