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.

“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, predators.

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...
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, mudflats 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.”

This 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 early researchers in that we are studying the health and function of entire ecosystems, rather than that of individual species like humans.

"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 Jen has collaborated 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 research," he explains. "I am 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.

"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 enthu- siasm 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…. We are inter-connected. 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.

For more information, contact Mark Hay, School of Biology, Georgia Tech, Atlanta, GA 30332-0230. (Phone: 404-894-8429) (E-mail: mark.hay@biology.gatech.edu)
Specialized researchers in various disciplines can have about as much trouble understanding each other as did Abbott and Costello in their “Who’s on first?” comedy routine. Yet many researchers agree that their coherent interaction is critical to addressing scientific and technological challenges facing society in the 21st century. Having ... in academia are re-educating themselves and giving graduate students a broader exposure to their own and other disciplines.

Such a trend is evident at the Georgia Institute of Technology in the field of aquatic chemical signaling. With a five-year, $2.7 million Integrative Graduate Education and Research Training (IGERT) grant from the National Science Foundation in 2001, the institute established an aquatic chemical signaling research center and interdisciplinary graduate training program. The program is open to students in Georgia Tech’s schools of Biology, Chemistry and Biochemistry, and Civil and Environmental Engineering.

Conducted in collaboration with the Scripps Institution of Oceanography and the Skidaway Institute of Oceanography, research and graduate education focus on chemical communication among organisms in both marine and freshwater systems. Their chemical signals affect critical processes such as feeding, competition, mate recognition and habitat choice. These signals also produce indirect effects on population structure, community organization and ecosystem function.

Faculty members model the kind of interdisciplinary interaction they want to teach graduate students, says School of Biology Professor Mark Hay, who leads the IGERT program. “We are holding hands across multiple boundaries,” Hay says. “So we have a great potential to address new questions, or to solve old, but previously intractable, questions in new ways.” Students in the IGERT program start their training with a series of integrated core courses that address the biological, chemical and physical interactions affecting aquatic signaling.

One of the first orders of business is teaching students enough about each other’s disciplines to have a meaningful discussion of research problems, says Assistant Professor Marc Weissburg of the School of Biology. “When we started working together, it took us about a year to get a common vocabulary,” Webster says. “We often get caught up in the lingo of our own disciplines.” IGERT students, on the other hand, will have an advantage in this regard when they begin research careers, Weissburg adds. “From the moment these students enter Georgia Tech, we begin to break down the barriers between the disciplines. I spent three years getting the vocabulary, but these students already have it when they go out into the world.” Assistant Professor Frank Loeffler of the School of Civil and Environmental Engineering also emphasizes the importance of interdisciplinary communication. He, too, draws from his experience as a microbiologist working among environmental engineers.

“We are educating new students broadly, teaching them to communicate with people in other disciplines,” Loeffler says. “If people can’t communicate, they often don’t like each other…. So it’s important to understand where others are coming from.” After taking some core courses, graduate students form interdisciplinary teams to investigate research questions of their own design. Meanwhile, students attend seminars that address scientific ethics, special issues faced by underrepresented groups and women in science, scientific education and outreach to the public, and the practical aspects of professional development in science and engineering.

In a seminar planned for next year, Assistant Professor Julia Kubanek of the School of Biology will prepare students to educate the public. The class will hear from experts in public policy, politics and journalism. “It’s a challenge to make science accurate and relevant to the public and to train young scientists to be people persons,” Kubanek says.

Meanwhile, Loeffler shares with students the foundation for his professional success in working with environmental engineers — a broad undergraduate and graduate education. Educated in Germany, Loeffler is a product of the interdisciplinary training trend that began in Europe a decade ago and is now catching on elsewhere.

“Companies have often hired young graduates who have specialized in one field,” Loeffler says. “So Interdisciplinary training prepares students to address a broad range of scientific questions.

**The Broad Side**

by JANE M. SANDERS

... students to address a broad range of scientific questions.

Far Left: Georgia Tech graduate students Deron Burkepile, Brock Woodson and John Parker (not pictured) conducted research at the Skidaway Institute of Oceanography in the summer of 2002.

Below and inset: Professor Mark Hay works with Amanda Hollobe, a graduate student in Georgia Tech’s School of Biology, as part of a summer research project at the Skidaway Institute of Oceanography.
Traditionally there was not a need for students trained in multiple disciplines. But in general now, a broad education is recognized as important, and the ability to communicate with other disciplines is critical.

With industry espousing this philosophy, academia is finding itself in direct competition with companies for the most broadly trained graduates. So one of NSF’s goals for IGERT is to attract more graduate students to careers in academia, Loeffler adds. To compete with industry, IGERT offers graduate student stipends a little higher than the average. And a companion goal is to have those young researchers pursue careers in the United States, rather than abroad. Thus, only U.S. students are eligible to receive IGERT funds.

Another opportunity for IGERT students is participation in internships at government labs, non-government organizations, biotech companies and other scientific institutions, such as Skidaway Institute of Oceanography in Savannah, Ga.

In the summer of 2002, teams of graduate students worked at Skidaway on research projects in aquatic chemical signaling. In one study, Deron Burkepile, John Parker and Lee Smee III investigated “Conflicting Chemical Cues” in the prey/predator behavior of blue crabs in estuarine tidal creeks. Their field study revealed that blue crabs were attracted to the odor of dead fish, but sacrificed these foraging opportunities when they were also confronted with the odor released by freshly injured crabs upstream from them, Furner explains. The crabs respond to chemical odors by fleeing, fleeing or hiding, which may have far-reaching ecological consequences, such as changes in habitat use by crabs and their prey.

“Further investigation of crab responses to conflicting chemical cues is needed to clarify how avoidance behaviors may help to structure natural communities,” the students wrote in a synopsis of their project.

Projects such as these get students to solve problems by interacting and thinking broadly about science, Kubeck says.

In both research and graduate training, she adds: “We are trying to build up from a mechanistic level to understand how the ecosystem functions – how species interact and how the environment itself shapes interactions. Things like energy flow, temperature and movement of water can affect reproduction. For example, some species cannot recognize mates in high-flow environments. If we know this sort of information, we can predict the success of various populations in various environments.”

For more information on Georgia Tech’s IGERT program, visit www.biology.gatech.edu/igert.htm.

Or, you may contact Mark Hay, School of Biology, Georgia Tech, Atlanta, GA 30332-0230. (Telephone: 404-894-8429) (E-mail: mark.hay@biology.gatech.edu).

Information on IGERT programs at other institutions is available at www.nsf.gov/home/crssprgm/igert/start.htm.
Aquatic animals track food and mates by their odors.

Mark Hay studies the ecology of “yuck” … the chemical defenses that aquatic organisms use to fend off predators...

In some cases, these small animals are so specialized that they sense and use only one of these structurally similar chemicals in the same plant to cue the glowing behavior and thus deter local fish, he says.

“What has driven the evolution of specialized feeding on these toxic plants is the need to avoid predators, not something that is great about the food,” Hay says. Terrestrial ecologists are documenting similar patterns, he adds, citing the gypsy moth as an example. This moth eats plants high in tannins (a chemical used in tanning leather). Even though the tannins are difficult to digest, the moth eats them because the toxins protect it from attack by microbes.

Similar patterns of chemical defense in marine and terrestrial ecosystems are not that surprising to Hay considering the complex cascades of indirect interactions between these environments, he says. The professor cites an example from one of his current studies funded by the National Science Foundation. He and colleagues at the Skidaway Institute of Oceanography near Savannah, Ga., are examining Phaeocystis, one of the most abundant genera of phytoplankton in cold oceans.

“These organisms are the primary producers in several arctic and sub-arctic seas and so form the critical base of the food web. Sometimes they are palliative and sometimes not,” Hay says. “It’s really variable. We are testing the hypothesis that they may be sensing the presence of consumers and producing more defensive chemistry in response. If so, this could determine whether their productivity cascades up the food web to support fisheries or is largely unused and sinks through the water column, supporting primarily bacteria and the detrital food web.”

Specifically, some Phaeocystis species respond to consumers — primarily zooplankton — by releasing a chemical called dimethylsulfide (DMS), which reduces feeding by zooplankton. Some species of small seabirds that eat zooplankton apparently sense this release of DMS, which guides their flight above more than a hundred miles of featureless ocean to find high-productivity areas where they can be the first to feed on zooplankton that concentrate there. Larger birds, such as albatrosses, follow the smaller, more sensitive birds and feed on fish that are attracted to these sites. These birds then fly back to their nests, often on desert islands, where they feed their young, deteriorate and sometimes get eaten by terrestrial predators.

Stable isotope studies indicate that this marine-based input of energy and nutrients influences the growth of desert vegetation, such as cacti, and animal populations, such as coyotes and spiders.

“Where’s that Smell?”

... Aquatic animals track food and mates by their odors...

...Aquatic animals track food and mates by their odors...
can better receive chemical signals necessary to easily navigate upstream. This takes a lot of energy because of increased drag force, but they decide it’s worth the effort for the payoff, he adds.

The researchers have also examined the chemical signal effects of environmental conditions, such as roughness on the ocean floor and its associated increase in turbulence. In rough areas, such as an oyster reef, chemical odors are diluted, and animals such as blue crabs have difficulty sensing them. Meanwhile, tidal channels are sandy, smooth environments with high-concentration patches of odors that are easily detected by blue crabs.

“This is where management issues come into play,” Weissburg says. “Turbulent environments provide a refuge for animals that blue crabs find using their sense of smell. Clams are a good example. If you farm clams, then you want their environment to be reasonably turbulent. . . . So there are a lot of real-world applications for this research.”

Another application for these research findings is in technology development programs—such as a U.S. Defense Department robotics initiative—based on biological design, he adds. That program funded some of Weissburg’s and Webster’s initial studies four years ago. The hope is that researchers can use their understanding of chemical signaling to design algorithms for devices such as odor-tracking robots.

“For example, if you build a robot, one initial question is how many sensors you put on it and where,” Webster explains. “If we have a firmer understanding of how animals respond to chemical signals, we can help in design projects. It may tell us we need a minimum 10-centimeter spacing between sensors or that we need sensors that respond rapidly to abrupt concentration changes. Do we want to act like a blue crab that can respond to signals quickly, but doesn’t perform well in turbulent environments? Or do we want to respond like a starfish that senses more slowly but performs well in highly mixed plumes?”

The understanding researchers are seeking depends on more research. The work is part of a larger body of research on copepods and their ability to navigate through it.

As their research collaboration continues, Weissburg and Webster plan to observe animal behavior in the flume while simultaneously visualizing the odor plume with lasers. “There’s a correlation there, and we’ve probably been missing some important subtleties that make the process work,” Weissburg adds.

Jane M. Sanders

For more information, contact Marc Weissburg, School of Biology, Georgia Tech, Atlanta, GA 30332-0230. (Telephone: 404-894-8433) (E-mail: marc.weissburg@biology.gatech.edu); or Don Webster, School of Civil and Environmental Engineering, Georgia Tech, Atlanta, GA 30332-0355. (Telephone: 404-894-6704) (E-mail: dwebster@ce.gatech.edu).
Researchers plan to further isolate and characterize the gene responsible for these proteins, which give the molecule its structure and functionality. They want to know how the gene differs among rotifer species to prevent hybridization between species, Snell adds.

Though it may seem inefficient in their vast aquatic environment, male rotifers depend upon their chemical sense—akin to the human sense of taste, rather than smell—to find the right mate. “With their fast swimming speeds, small body size and high population density, they will contact each other with virtual certainty during their reproductive cycle,” explains Snell, who has conducted field work throughout the United States, and in Spain, Costa Rica, Japan and Israel. “Their densities typically range from one to 100 animals per milliliter. So they bump into each other often. When they do, the male must decide if he has contacted food, a predator or a mate. If the female’s surface chemicals signal that she is female and of the right species, the male will attempt to mate with her. He has only 30 sperm for his entire lifetime, and he injects three to four sperm per copulation. So he better not make too many mistakes.”

The mating signal on female rotifers’ bodies are critical for reproductive success, Snell adds. “These mating signal proteins are important evolutionarily. They determine species boundaries and are critical to the male’s ability to recognize females of his own species.”

In research funded by the National Science Foundation, Snell’s research team has collaborated with School of Biology Assistant Professor and biochemist Julia Kubanek to isolate and characterize a surface glycoprotein on female rotifers. “We have been able to remove the glycoprotein from the females and attach it to females from a closely related species to see if we can trick males into mating,” he explains. “We have found that the glycoprotein cue is both necessary and sufficient by itself to trigger the male mating response.”

Snell has found similar mating signals in copepods, another type of zooplankton species closely related to shrimp. “The molecule we have characterized is a key molecular determinant of species boundaries and regulating the process of speciation in zooplankton,” he says.

Researchers plan to further isolate and characterize the gene responsible for these proteins, which give the molecule its structure and functionality. They want to know how the gene differs among rotifer species to prevent hybridization between species, Snell adds.

In a related research effort, Snell’s research team is studying the effects of pollution on zooplankton chemical communication. “We don’t yet know what kinds of compounds specifically interfere with mating,” Snell says. “But they could have a variety of effects. Some of them probably alter the male mating response. Recently in our lab, we found compounds that do not seem to affect male or female survival, but they disrupt mate recognition. We don’t know the compounds yet. They could be contaminants in the lab, such as a bacterial waste product or something in the plastic dishes we use. … Zooplankton are extremely sensitive to certain compounds, but they can tolerate a ton of others,” Snell adds. “Their most sensitive system is their sexual reproductive system. Mate recognition is a key component of that.”

Isolating and identifying the toxins affecting mate recognition is a complicated process that could take years, Snell adds. Meanwhile, Snell’s research team has already collected evidence that other aspects of rotifer reproduction are affected by chemical contaminants in natural environments. “Chemical compounds may be affecting the reproductive systems of zooplankton in natural environments could have a ripple effect, Snell explains. “We’re looking at their lives with a diet of rotifers because rotifers are the right size and easy to catch. So fewer rotifers would, in turn, yield fewer larval fish to grow into big fish.” — Jane M. Sanders
**Key Ingredient**

Organic chemist’s contribution is essential to biological studies of aquatic chemical signaling.

Key to unlocking some of the mysteries of chemical signaling in aquatic species is the expertise and techniques of an organic chemist.

In Georgia Tech’s aquatic chemical signaling research initiative, chemist Julia Kubanek, an assistant professor in the School of Biology and School of Chemistry and Biochemistry, provides that key. She employs chemical techniques in the laboratory to answer ecological questions and ultimately to address human health issues.

One of her primary studies — for which she recently received a National Science Foundation Career Award — centers on the chemically mediated interactions between aquatic microscopic plants and animals called phytoplankton and zooplankton.

Specifically, she is investigating why some phytoplankton get eaten and others — such as toxicalgae — don’t get consumed by zooplankton. Scientists believe certain chemical defenses shape the ecological community. Here, Kubanek sorts specimens collected during a research cruise.

Assistant Professor Julia Kubanek and her colleagues at the Scripps Institution of Oceanography have investigated a seaweed called *Lobophora variegata*, left, and discovered it has a strong antifungal potency and potentially some cancer-fighting power.

Kubanek and some colleagues at the Scripps Institution of Oceanography in San Diego, Calif., and the University of North Carolina at Wilmington have focused on marine sponge chemical defenses against coral reef fishes, against competing sponges, against settling larvae, and against biofilm-forming bacteria.

Using this sort of ecologically driven assay is a new way for finding novel pharmaceuticals, Kubanek says. The rate of discovery of new drugs has slowed dramatically in recent years, but this method could improve that search.

For more information, contact Julia Kubanek, School of Biology, Georgia Tech, Atlanta, GA 30332-0230. (Telephone: 404-894-8424) (E-mail: julia.kubanek@biology.gatech.edu)

Julia Kubanek sorts specimens collected during a research cruise.

**Signals in the Sea**

Assistant Professor Julia Kubanek and her colleagues at the Scripps Institution of Oceanography have investigated a seaweed called *Lobophora variegata*, left, and discovered it has a strong antifungal potency and potentially some cancer-fighting power.

With the chemical techniques in the laboratory, Kubanek incorporates various compounds from phytoplankton into artificial food matrices that zooplankton either feed upon or ignore. To further understand these processes, Kubanek wants to determine the physiological effects of zooplankton’s diets.

“Do they grow more slowly or lay fewer eggs because of the chemical compounds they consume or avoid?” Kubanek asks. “In turn, what effects does this selective eating have on the biology of phytoplankton? Similar questions have been asked and answered in terrestrial systems. For example, skunks are chemically protected from predators with the foul smell they can spray. But little work has been done in aquatic environments.”

In other research, Kubanek is collaborating with School of Biology Professor Mark Hay on the chemical defenses of plants and animals that inhabit coral reefs. They want to know how those chemical defenses shape the ecological community.

“Are they a force for structuring the communi- ty and, in the long term, a force for the evolution of the community?” Kubanek asks. “We don’t have a complete picture yet.”

Kubanek and some colleagues at Scripps focused on marine sponge chemical defenses against coral reef fishes, against competing sponges, against settling larvae, and against biofilm-forming bacteria.

In laboratory experiments, researchers fed bits of sea sponge to fish and crabs, which spit it out. Then they extracted chemical compounds from the sponge, placed the extract on a piece of highly favored squid, and again the fish and crabs rejected the food, Kubanek explains. Next, they separated out thousands of chemical compounds from the sponge into water-soluble and non-water-soluble fractions. They combined the water-soluble fraction with a food pellet and fed it to fish and crabs, which again rejected the meal.

Now, they are separating the water-soluble compounds into 10 fractions and testing each on a piece of squid provided to fish and crabs. The latter ignored only 10 percent of the treated squid, leaving researchers with several compounds to test further. They hope to soon discover the compound that fish and crabs find repulsive.

“It’s probably a new compound,” Kubanek says. “We have searched the literature for related species and haven’t found any. If we discover an exotic structure that affects predators, the commercial potential for this compound opens up.”

Using this sort of ecologically driven assay is a new way for finding novel pharmaceuticals, Kubanek says. The rate of discovery of new drugs has slowed dramatically in recent years, but this method could improve that search.

As an example, Kubanek cites a study she started as a postdoctoral fellow at Scripps and has finished since she joined the Georgia Tech faculty. Kubanek and her colleagues investigated whether seaweeds in the ocean can avoid infection by fungi and bacteria by producing their own natural antibiotics. The seaweeds live in constant contact with potentially dangerous microbes, suggesting they are under pressure to evolve some kind of resistance, she explains.

Her colleagues at Scripps devised a bioassay to measure the antimicrobial potential of seaweeds. They combined biological extracts from seaweed with a fungus or bacterium and monitored the sample to see if the microbes grew. More than half of the 55 microbial species responded to some antibacterial property in the seaweed. This suggests that some natural compound in seaweeds is suppressing the growth of microbes, Kubanek explains.

It appears that the researchers have discovered a new antibiotic with a complex chemical structure that is somewhat similar to other antibiotics produced by terrestrial bacteria (thus researchers have not applied for a patent yet). The compound has a strong antifungal potency and potentially some cancer-fighting power, as well, Kubanek adds. The pharmaceutical company Bristol-Myers Squibb is a partner with Scripps and is collaborating on the ongoing research. Scientists still need to determine whether the seaweed is actually the original source of the antibiotic.

Meanwhile, Kubanek also collaborates with colleagues Jeannette Yen and Terry Snell (see “Hot on the Trail” and “Avoiding Costly Mistakes” — J.M.S.)

— J.M.S.

For more information, contact Julia Kubanek, School of Biology, Georgia Tech, Atlanta, GA 30332-0230. (Telephone: 404-894-8424) (E-mail: julia.kubanek@biology.gatech.edu)

Julia Kubanek, an assistant professor in the School of Biology and School of Chemistry and Biochemistry, is collaborating with School of Biology Professor Mark Hay on the chemical defenses of plants and animals that inhabit coral reefs. They want to know how those chemical defenses shape the ecological community. Here, Kubanek sorts specimens collected during a research cruise.
Signals in the Sea

Frank Loeffler wants to take advantage of microorganisms. Loeffler, a microbiologist and assistant professor of environmental engineering at Georgia Tech, believes he can exploit the natural chemical communication processes of marine organisms, including microorganisms, to clean up sites contaminated with chlorinated compounds.

“We need to understand how organisms work and then implement an engineering solution using what we know from microbiology,” Loeffler says. Engineers sometimes introduce microorganisms to degrade contaminants at a polluted site or stimulate microorganisms that are already present there to do the job. Such strategies are called bioremediation.

Finding the right microorganisms to make these strategies work is challenging, but promising, in marine environments. Many higher aquatic organisms communicate with chemical signals that are actually chlorinated compounds produced by the organisms to perform some basic function, such as predator protection, Loeffler explains. For example, a species of algae produces a chlorinated compound that deters some species of fish from eating it.

“We want to take advantage of these signaling processes,” Loeffler says. “So we are studying the guts of fish to see what microorganisms are present and being used to break down chlorinated compounds. Then we can exploit the microorganisms for use in various polluted environments. Some fish won’t eat a certain plant because the plant is protecting itself by producing chemicals that don’t taste good. But other fish actually eat toxic compounds. The microorganisms we are finding in them are most promising for bioremediation applications.”

There is no shortage of naturally produced chlorinated chemicals in marine environments, especially in warmer climates, Loeffler adds. In a study that began in August 2002, Loeffler collected two types of fish off the coast of south Florida. One species eats algae containing a chlorinated compound, and the other does not.

“We are looking at the microbes in the intestines of these fish,” Loeffler says. “What can they do? What we find may lead to new discoveries.”

Researchers are identifying the chlorinated chemicals they believe the fish consume in their diet. Then in the lab, they can selectively enrich for the microbes that break down the chlorinated compound in the fish’s gut. The ultimate result is a single population of the target microorganism. Research can then focus on how to use that organism for bioremediation.

Loeffler hopes his research will help change the environmental engineering professor’s approach to bioremediation. Now, engineers typically take samples from a contaminated site to see what microorganisms are present and which ones might be exploited for clean up. But Loeffler suggests that bioremediation efforts should begin with research on natural environments where microorganisms are often abundant and have had time to genetically adapt to naturally occurring low levels of chlorinated chemicals.

“In an evolutionary timeframe, 10 to 20 years of contaminant exposure is not enough time to develop the biological machinery to degrade chemicals efficiently at polluted sites,” Loeffler says. “But a natural environment is a good place to find the source of the genetic information — the organisms degrading lower concentrations of contaminants. These organisms have had time to specialize to take advantage of this chemistry.”

It is still an open question whether such microorganisms can degrade higher concentrations of contaminants, Loeffler adds. “Often, that’s a limiting factor for degradation. But we may be able to manipulate the system to enhance their capabilities. We are looking for clues about how they degrade the chemicals.”

In the process, researchers such as Loeffler want to know the ecological effects of introducing organisms to clean up contaminants. He and others are using nucleic-acid-based tools to monitor communities and quantify microorganism populations that are degrading the toxic chemicals.

“In my experience, the organisms have had no negative impact on the environment,” Loeffler says. Overall, the community structure returns to its natural state following the bioremediation treatment, according to Kirsti Ritalahti, a postdoctoral researcher in Loeffler’s group.

— Jane M. Sanders

For more information, contact Frank Loeffler, School of Civil and Environmental Engineering, Georgia Tech, Atlanta, GA 30332-0512. (Telephone: 404-894-0279) (E-mail: frank.loeffler@ce.gatech.edu)

Researchers are examining the guts of parrotfish, above, to identify the chlorinated chemicals they believe the fish consume in their diet. Then in the lab, they can selectively enrich for the microbes that break down the chlorinated compound in the fish’s gut. The ultimate result is a single population of the target microorganism. Research can then focus on how to use that organism for bioremediation.

Assistant Professor Frank Loeffler, a microbiologist, and postdoctoral fellow Kirsti Ritalahti want to exploit the natural chemical communication processes of marine organisms, including microorganisms, to clean up sites contaminated with chlorinated compounds.