WILLIAM & MARY

To harness the wild algae

On the lake: Karl Kuschner pulls around the Matoaka flume while physicist William Cooke and students work with the substrate screens. The researchers access the Matoaka flume by jonboat, while the York River flume is accessed by a pontoon boat—the R/V Shrödinger's Cat-amaran—which also serves as a working platform.

Photo by Joseph McClain

Challenges abound, but the potential payoffs are enormous

By Joseph McClain | November 30, 2010

At first glance, algae seem like ideal candidates for biofuel. After all, each algal organism has at its center a dab of energy-rich oils and sugars. If you get enough algae, you can extract the oil—or ferment the sugar into alcohol—and use it to put a sizeable dent in the world's thousand barrel per second petroleum consumption. The algae might also be useful for other products, such as organic fertilizer.

The concept is impeccable in theory, but conversion of aquatic plants to fuel includes a number of scientific and engineering challenges, especially when the idea is to use wild, naturally growing algae for feedstock.

An interrelated set of initiatives at William & Mary and its Virginia Institute of Marine Science is taking on those challenges. The Chesapeake Algae Project, or ChAP, was started with $3 million in start-up funds from Statoil, the Norwegian energy company. In addition to Statoil, ChAP involves other corporate partners, including HydroMentia, a company that specializes in water treatment technology, and the Williamsburg energy consulting firm Blackrock Energy. ChAP also includes researchers from the Smithsonian Institution, University of Maryland and the University of Arkansas, as well as from several departments at William & Mary and VIMS.

In September, the U.S. Department of Energy awarded William & Mary $500,000 to support the pursuit of some basic-science issues that will inform the ChAP initiative. Most algal fuel research projects are based on the cultivation of a single species of algae that has high lipid content. But Dennis Manos, William & Mary's vice provost for research, notes that ChAP differs from other algal biofuel initiatives in using wild, naturally growing algal species as a basis for various energy products.

The wild-algae approach has a number of benefits over monoculture approaches. For instance, Manos points out that wild algae make up for their lower lipid content by being more robust, fast-growing and plentiful: "If I can grow three grams of something that's half as efficient in the time it takes you to grow one gram of something that's perfectly efficient, I still win."

Manos says the scientific literature has very little data relevant to a wild-algae biofuel initiative. Almost all the scientific study of algae to date has focused on single algal species, he said, while a successful multispecies biofuel initiative requires a deep understanding of algae colonies.

"All the previous study has been on the physiology of algae," Manos said. "Now we need to understand the ecology of algae. We want to use algal colonies as biofuel feedstock, so we need to be able to look at the life of a colony over a long period of time and to predict the effects of various changes in the environment."

Potential biofuel products

Once the initiative reaches industrial levels, there are a number of potential biofuel products that could be produced, he noted. Biodiesel can, of course, replace petroleum diesel, while biobutanol could be used in gasoline engines. Researchers are also studying the feasibility of cofiring—using algal biomass to augment the coal burned in power plants .

ChAP and the related algae biofuel initiatives are part of an effort to bring about an environmental "twofer," combining environmental remediation with biofuel production. Algae are efficient filters of impurities and remove a variety of contaminants from the surrounding water. Once you remove the algae from the water, the heavy metals and excess carbon and phosphorous come out, too.

Emmett Duffy, Loretta & Lewis Glucksman Professor of Marine Science from VIMS, says one important benefit of the project is "recycling on a grand scale." One of the anticipated byproducts of ChAP, he explained, would be algae-based agricultural fertilizer. Once the oil is removed from the algae, nutrients are left in the remaining biomass. It's recycling, Duffy explains, in that the nutrients came from agricultural runoff in the first place.

"Most human industry uses resources and then creates a lot of waste," he explained. "What we're trying to do is turn that around and use waste to produce resources. Basically, the algae remove pollution from the water and then we can repackage that to put the nutrients back where they belong, which is on the farm soil."

The scientists have launched two in-water flumes to monitor algae growth *in situ*. The flumes are basically floating laboratories, what research scientist Karl Kuschner calls a "40-foot hole in the water." They support a set of substrate screens and an array of instruments to monitor growth conditions. Teams deployed a freshwater version in Lake Matoaka over the summer, followed by a second research platform in the brackish water of the York River.

The Matoaka platform was launched in sections and paddled to moorings near the Keck Environmental Field Lab

The Matoaka version was constructed near the boathouse by faculty and students, using treated lumber and dock floats. The York River conditions required a welded metal construction for the flume. A pontoon boat docked at the VIMS Boat Basin —*RV Schrödinger's Cat-amaran*—serves as both a means of access and as a working platform for the York River flume.

Monitoring algae growth

These research platforms will allow the researchers to figure out how to optimize algae growth conditions, explained William E. Cooke, professor of physics at William & Mary. Algae will naturally attach themselves and grow on substrate screens positioned in the flumes, Cooke said. Each flume is outfitted with an array of scientific instruments to allow researchers to track a number of factors, such as nutrient reduction in the water and the rate and extent of algal growth. They are experimenting with a number of substrate materials in the flumes, beginning with what Cooke calls “plain old Home Depot window screen” and including sheet aluminum, burlap and high-density polyethylene.

“Usually, algae growth is measured by harvesting and drying,” Cooke said, “but we will use photometric methods to determine the growth before we harvest. That way we can determine the best time to harvest and the best method for harvesting.”

The science of wild-algae biofuels

The Department of Energy grant will allow a number of researchers to investigate a variety of basic-science topics necessary to the project. Cooke notes that the William & Mary/VIMS scientists are taking on questions that require intensive interdepartmental cooperation.

“The nice thing is that there are a bunch of people here at the College who are more than willing to be interdisciplinary and try something new, ” Cooke said. “So we are a little faster on our feet than other places where people have their empires and say ‘No, I have to see a way how this fits into my empire’.”

The DOE grant is allowing scientists to investigate the following questions:

• **How does pulsed water affect algal growth?** Cooke and Gene Tracy, the Chancellor Professor of Physics, will examine causes behind a phenomenon noted by fellow ChAP team member Walter Adey of the Smithsonian Institution. In developing the Algal Turf Scrubber® (technology now owned and patented by HydroMentia), Adey found that, in land-based systems, a pulsed flow of water enhanced growth of the algae. Cooke and Tracy’s team will try both to identify the specific mechanism behind the phenomenon and to determine how to take advantage of it in open-water algal flumes.

• **Are algal polycultures more effective at contaminant removal than single-species approaches?** Emmett Duffy and Elizabeth Canuel, professor of physical sciences at VIMS, will compare the relative efficiency of a community of many algal species as compared to an established monoculture of a single form of algae. Duffy and Canuel will continue studies already begun at the land-based floway at the VIMS campus.

• **To what degree are the algae processing aquatic contaminants?** A VIMS-based team led by Michael Unger, associate professor of environmental and aquatic animal health, will examine the process in which wild algae take up substances such as nutrients and carbon—and also organic contaminants and heavy metals—from the environment. The team, which also will include Canuel, will address the question of whether the algae break down contaminants chemically or just store them internally.

• **What’s the best biochemical preprocessing of algae for conversion into biofuel?** On William & Mary’s main campus, a team led by Rob Hinkle, associate professor of chemistry, will investigate novel ways to extract lipids and carbohydrates from the algae. The team will include Mark Forsyth, associate professor of biology, and Kurt Williamson, assistant professor of biology, who will investigate the use of bacteria and viruses to break down the hard outer algal cell wall.