The future of seaweed aquaculture involves polyculture — seaweed farms and salmon farms in symbiotic embrace.

# Seaweed Beyond Sushi

BY CATHERINE SCHMITT

Catherine Schmitt(2)

courtesy Susan Brawley

*(top) Nicolas Blouin on a collecting expedition. (middle) His car functions as a field laboratory. (bottom) His mentor Susan Brawley on their China trip.*

FIVE O'CLOCK IN THE MORNING on the coast of downeast Maine. It is hard to tell what time it is because there is no sun, only rain and wind and cold. Beyond the gray and the crashing green waves there are only a raft of eiders and then the fog.

The Schoodic Peninsula is almost empty, but Nicolas Blouin is there. He is hunting for a seaweed called *Porphyra*, also known as purple laver or nori, the black stuff that is wrapped around sushi. *Porphyra* is a red alga, and the deeper in the water it grows, the redder it gets. It turns black when dried. At low tide it coats the rocks with a slippery, shaggy carpet of purplish-brown fronds that grow above the rockweed zone. Blouin's rain-matted hair spikes up in the blowing mist of rain and sea spray as he picks *Porphyra* from the rocks, searching for the perfect specimen. He holds a blade up to the gray sky for closer inspection. Aloud, he ponders the seaweed's evolutionary strategy—it grows low enough below the tide to avoid physical stress, such as sun and wind, and high enough to be out of the reach of hungry crabs and snails.

What most of us call seaweeds are not true plants but marine macroalgae, members of the kingdom *Protista*, a misfit group of ancient organisms that are not quite plant and not quite animal (although taxonomists continue to debate this classification). It is an important group that serves as the base of the ocean food web. At least seven species of *Porphyra* are native to the New England coast. In Maine, most species are present only a few months of the year. For example, one type appears only briefly in December and January.

As the morning brightens to whitish gray, Blouin crouches in the makeshift field laboratory next to his beat-up Toyota, slicing up blades of the species *Porphyra umbilicalis*. As he explains its biology with a casual but accurate use of scientific terms, the conversation wanders: the best brand of rice cooker, what it's like to be a botanist, what it would be like to live in Canada, the pros and cons of restoring plaster, how genes get turned on or off. The topic of seaweed aquaculture doesn't get lost in the discussion, but instead provides a launching pad to talk about so many other things while he cuts tiny rectangles of seaweed with a razor blade, wraps them in aluminum foil, labels them, and drops the packets into a tank of smoking liquid nitrogen. Each piece represents a different part of the algae, with different types of cells. The cells on the edge of the blade reproduce, while the mature cells in the middle of the blade do not. Blouin will examine the RNA of the different cells to learn more about how the plant reproduces.

Blouin chose to work with *Porphyra umbilicalis* because it is present year-round and reproduces asexually, so it is easy to culture in the lab. Despite his expert knowledge of *Porphyra*, he says his favorite is the West Coast species *Sarcodiotheca gaudichaudii*, a "fun seaweed with a cool name that looks like Thai noodles."

Susan Brawley

*In China, nori is grown across hundreds of acres half a mile from shore in areas where there are shallow tides.*

Blouin's path to seaweed research was not necessarily a logical one. Born in France, he grew up a Navy brat and lived all along the East Coast of the United States. By the time he was in his late twenties, he was settling into a career as a magazine photographer in New York City, shooting portraits of celebrities, rock stars, and fashion models. At 31 he moved to Boston, and his camera became focused on a more natural subject: seaweed. Drawn to the beauty of his subject, Blouin began making pictures of seaweeds (above)using a cyanotype printing technique. Soon he found himself wanting to know more. He tracked down Jim Sears, a professor at the University of Massachusetts-Dartmouth, and began tagging along on class field trips.

BLOUIN BECAME WILD ABOUT SEAWEED. So wild that he followed Sears' advice and took a summer course at the University of Washington's Friday Harbor Laboratory, where he spent six weeks learning the taxonomy of seaweed. Thoroughly intrigued, he decided to go back to school for marine biology, and ended up in Susan Brawley's laboratory at the University of Maine.

Not every researcher would be willing to take on an older graduate student without a science background, but Susan Brawley had an open mind and took the chance on Blouin. Brawley had received funding from Maine Sea Grant to examine the potential for seaweed culture in Maine, and she hired Blouin as her graduate assistant on the project.

Today, Brawley and Blouin are collaborating with Cooke Aquaculture and scientists from the Chinese Academy of Sciences in Qingdao, China, to experiment with ways to grow seaweed near salmon farms in Cobscook Bay. Growing seaweed alongside salmon pens might reduce the excess nutrients that are the waste product of fish farming. In turn, the seaweed might benefit from the nutrients and grow faster.

The Environmental Protection Agency was impressed enough with the team's early work to award Blouin a presti-

Nicolas Blouin photo, *Porphyra amplissima*

# Seaweed Salad Anyone?

There are more than 250 species of seaweed (or sea vegetables) in the Gulf of Maine region. While most of them are technically edible, only a handful of coastal species are commonly consumed by humans.

illustrations by Andrea Sulzer (5)

**DULSE** (*Palmaria palmate*) grows as reddish-purple, hand-shaped fronds 6 to 12 inches long and attached to rocks or crevices. On the Maine coast, dulse flourishes on rocky outcroppings with moderate turbulence, in nutrient-rich reversing falls and strong currents in the summer. High in protein, potassium, iron, fluoride, and vitamin B6, dried dulse is a popular snack and a versatile sea vegetable.

**LAVER OR NORI** (*Porphyra umbilicalis*) can be found attached to rocks just above the rockweed zone. When exposed by the tide, laver looks like deflated black balloons. Laver is a good source of protein, manganese, zinc, copper, fluoride, B vitamins, and vitamins C and E. Laver is dried and pressed into sheets for sushi and other uses.

## Seaweed Beyond Sushi

**IRISH MOSS** (*Chondrus crispus*) is a common low intertidal red alga that grows in water up to 230 feet deep. Irish moss contains carageenan, which is extracted for use as a food additive stabilizer, emulsifier, and filler.

**KELP** (*Laminaria longicruris*) takes the form of long, broad, golden fronds that grow in subtidal areas. Kelp is a versatile sea vegetable and is similar to Japanese kombu. It is high in calcium, potassium, magnesium, and iron.

**WINGED KELP** (*Alaria esculenta*), is a brown alga of olive-brown fronds that grow up to 12 feet long. High in vitamin A and calcium, Alaria is similar to wakame and is used in soups and stews.

**SEA LETTUCE** (*Ulva lactuca*) is a thin, tissue-like green alga that can be seen in tide pools, washed up on the beach, or floating in shallow water. The whole-leaf plant is used raw, in soups, and for garnishes.

All listed varieties are available from MAINE COAST SEA VEGETABLES in Franklin, Maine. 207-565-2907; http://seaveg.com.

gious STAR fellowship in 2004; combined with additional funding from Maine Sea Grant, the fellowship will allow Blouin to continue his research for a doctorate degree.

"Any successful scientist has to bring together a group of skills," said Brawley. "Nic is adept at so many different things. He can do almost anything, from the lab bench to the field, to learning new knots from our friends at Cooke [Aquaculture]. This project needed someone like him, who can pick things up very quickly. He's creative and curious and hard working."

Seaweed thrives in the cold, clean waters of the Schoodic Peninsula, which is one reason why this spot has served as a research site for Brawley and other researchers for more than a decade. "So much of the Maine shore is private, and it can be very difficult for a marine biologist to find places to work," said Brawley. Because Schoodic is part of Acadia National Park, researchers have access to the coastal sites that are also home to lots of different kinds of organisms.

Blouin races to Schoodic in the early morning hours from his Bangor home so he can collect *Porphyra* before the rising sun begins to take a toll on the fragile blades. An early start also gives him a long day to process samples in Brawley's lab at the University of Maine.

Back in the lab, Blouin places bits of the freshly harvested *Porphyra* in dishes, where they float beneath the fluorescent light like pieces of purple cellophane. As he waits for the fragments to release spores, he moves to a microscope to check the progress of three-week-old *Porphyra* cells, then to his office where photographs of seaweeds hang on the walls and nori-flecked rice balls warm in a hotpot on his desk. He scrolls through pictures from his trip to China, where he and Brawley went to learn seaweed culture from the masters.

Xiugeng Fei, a professor at the Chinese Academy of Sciences in Qingdao, has been studying seaweed for more than 50 years. Brawley and Blouin are collaborating with Fei and Dr. Peng Jiang to experiment with culture methods in Maine. "The Chinese have focused a lot of resources over a period of 50 years to get to where they are now, which is world leaders of sea vegetable mariculture," said Brawley, "What we're trying to do here in Maine is to bring together groups who are trying to grow and

process *Porphyra*—like Maine Coast Sea Vegetables—and those who are trying to sustainably culture finfish, like Cooke."

"I had heard how large the operations were in China," says Blouin, "but I don't think I was aware of the extent of it. You name it, they grow it."

Like many other seaweeds, *Porphyra* has an interesting life cycle, in which the leafy stage alternates with a microscopic, sporific form. If the organism can be controlled to produce blades, rather than going through the microscopic stage, it will be easier to produce for commercial use. Meanwhile, Blouin is growing some *Porphyra* from spores using traditional culture techniques.

This is the purer science part of Blouin's graduate work. When asked which he likes more, the strict science or the applied aspects, he says both. "It keeps it interesting to me. Otherwise, I'd be bored."

The applied part of the project is 70 miles east, in Cobscook Bay, where the researchers are testing the seaweed growing process on the salmon aquaculture lease sites of Cooke Aquaculture (formerly Heritage Salmon). Nets "seeded" with *Porphyra* are placed at various distances from Cooke's salmon pens to determine the most effective location to grow the seaweed.

They have found that the nets should sit about three meters below the water surface, says Blouin. Any closer and too much light and heat will kill the seaweed. But the seaweed also needs to dry out periodically, as would happen naturally as the tides rise and fall. Regular drying keeps other small algae from growing on the surface of the seaweed.

In China, nori is grown across hundreds of acres half a mile from shore in areas where there are shallow tides. Workers get out to the nets by foot, by boat, or by oxen. After the trip to China, the researchers realized that a similar operation would never work in the United States, because of the cost of labor. Instead of hiring people to tend the nets, they would have to automate the process. For that, they turned to Mick Peterson, an associate professor of mechanical engineering at the University of Maine, who is developing a way to automatically raise and lower the rafts that hold the nets.

The nets also need to be close enough to the salmon pens to absorb waste products, but not so close that they would get in the way of operations. "Ultimately, it's up to the salmon industry to want to do this, not us," says Blouin. It appears that they do: Cooke has provided infrastructure, technical expertise, and assistance with boats, said Jennifer Robinson, compliance officer and fish health specialist with Cooke Aquaculture. The company has been impressed with the work ethic of Brawley and Blouin. "They didn't just come in and say, 'this is how we are going to do things,'" said Robinson. "We really worked as a team. They listened to us and took a lot of our ideas."

This isn't the first time there have been attempts to culture nori in New England. A decade ago, a company named Coastal Plantations unsuccessfully tried to grow a Japanese species in Cobscook Bay. Now, the focus is on using species that are native to the Maine environment and naturally grow well here.

"Nic and Susan have picked up where Coastal Plantations left off, by looking at native species," says Mike Hastings of University of Maine's Office of Research and former director of the Maine Aquaculture Innovation Center. "They are part of a group of pioneers who are looking at the culture of new species."

Multi-species marine aquaculture, or polyculture, is a relatively new concept in Maine; in New Brunswick, Cooke has experimented with growing kelp and mussels near salmon farms. Research by Shawn Robinson of the Canadian Department of Fisheries and Oceans in St. Andrews has shown that mussels grown near salmon pens take up excess feed, grow up to 50% faster, and are higher in omega-3 fatty acids than those grown elsewhere. Kelp growth rates have also increased. Robinson says that the industry is moving away from monoculture and toward a more ecological model that recycles waste and nutrients—"industrial ecology" that attempts to fit human activity into the natural system. Plus, growing another product is a way to get more profit out of an aquaculture lease site: Robinson estimates that growing mussels and seaweed on salmon farms could add 207 jobs and $44 million to the Maine economy.

Recognizing that polyculture has both economic and ecological benefits, and that it is one way to manage discharges from marine aquaculture, the Governor's Task Force on the Planning and Development of Marine Aquaculture in Maine recommended that the state promote the further use of that technique. Brawley's research team is helping to further that goal. As in most pilot studies, the researchers are trying to work out the sensitive stages of the seeding-to-salmon farm process, so the nori nets can be sold and used commercially. At the Cooperative Center for Aquaculture Research in Franklin, Blouin has placed seaweed in experimental flumes and measured how well it takes up nutrients from fish effluent.

"This summer we are going for broke and putting out a lot of nets," says Blouin. "Hopefully we'll get a real crop, enough to show that this is a feasible industry."

Another reason to develop culture techniques is that there are concerns that harvesting wild seaweed may have a negative impact on the natural system. The practice of seaweed harvesting has been controversial in the past; studies have shown that cleared wild areas don't grow back.

Yet seaweed is a valuable resource. The nutrients and minerals that seaweeds soak up from the ocean are what make them such nutritious food for humans. Manufacturing nori sheets for sushi is a $2 billion industry in Japan alone; Asian species of *Porphyra* have been used for food and medicine for more than 2,000 years in Japan, China, and Korea.

Brawley recognizes that a seaweed market in Maine is not going to be built on sushi alone. Seaweed can be used as a seasoning in powder and flake form, as a vegetable, and as a supplemental source of protein, vitamins, and nutrients. Brawley believes that Maine can make strides in the global market if local businesses can find ways to incorporate seaweed into western diets. As part of the project, she is collaborating with Maine Coast Sea Vegetables in Franklin, the University of Maine Dining Services, and Professor Denise Skonberg from the University of Maine's Department of

Food Science and Human Nutrition to develop a domestic market for *Porphyra* that goes beyond traditional Asian cuisine. In December 2005, for example, the University's Maine Marketplace held a sea vegetable promotional day with dishes created by university chefs. The successful event won a gold award from the National Association of College and University Food Services.

Chris Bartlett, an extension associate with Maine Sea Grant's Marine Extension Team, who has been helping with the project, notes how unusual it is for researchers to focus on so many aspects of a subject at once. "Most people would just try to get the experiment to work and worry about the marketing later," says Bartlett, "but Susan and Nic are doing things differently."

As the project continues, the researchers will profile the nutritional characteristics of *Porphyra umbilicalis*, and continue to help move the process of growing seaweed from the lab to the commercial sector. But Blouin, an artist at heart, is more interested in the seaweed itself than the business end of the project. He even claims that he is more of an aesthete than a scientist, but others may be tempted to disagree given his success on such a complex, interdisciplinary research project. In the end, if Maine's seaweed and aquaculture industry continues to grow, and people of Maine eat more nutritious, locally grown food, Blouin and Brawley will be partly responsible.

*Catherine Schmitt has been a science writer with the Maine Sea Grant Program at the University of Maine, Orono, since 2004.*

**MORE INFORMATION**

As seaweed becomes more popular and valuable as a commercial product, there are concerns that over-harvesting may impact seaweed populations. Maine enacted a seaweed harvesting permitting system in 1999 and the Department of Marine Resources regulates harvesting in the state. Guidelines and licenses for harvesting Maine's seaweeds are available from the DMR: www.maine.gov/dmr.

MAINE SEAWEED COMPANY, www.alcasoft.com/seaweed, Steuben, is a small, family company that offers hand-harvested dried Atlantic seaweeds.

Maine seaweed is not just for eating. It provides the raw material for many commercial products. Seaweed is an important ingredient in organic compost and fertilizer. OCEAN ORGANICS, Waldoboro, specializes in seaweed products for golf courses; COAST OF MAINE ORGANIC PRODUCTS offers a seaweed mulch, and ATLANTIC LABS makes seaweed-based fertilizer and an animal feed supplement. NORTH AMERICAN KELP, www.noamkelp.com, Waldoboro, sells kelp products. ACADIAN SEAPLANTS OF NOVA SCOTIA, www.acadianseaplants.com, provides sea vegetables and derivatives for various commercial uses.