



Researcher gives hope to developing countries

by Angela S. Miller

The hundreds of lab books lining the shelves of Dr. Maxwell Doty's cluttered office at the University of Hawaii contain scientific notes from a career that spans more than 50 years. Another part of his story could be told by the thousands of people whose lives Doty has touched directly and indirectly by turning his botanical discoveries into practical applications.

In more than 20 years of Sea Grant supported research, Doty has gone beyond pure academic study to working with real people and real problems. Dr. Jack Davidson, director of the University of Hawaii Sea Grant College Program, said Doty's success in all three phases of the Sea Grant mission; research, education, and extension to public use; makes him a model for other investigators. "Dr. Doty not only developed fundamental techniques and technology, but he also put them into practice in a very successful new industry," Davidson said.

Today, approaching 80 years old and "60 percent" retired from the University of Hawaii since 1987, Doty finds humor in the turns his career has taken. "I started out pressing plants like a good botanist and I wandered into experimental sociology," he said with a chuckle.

The "social experiment" he directed helped to advance an international commercial industry and introduce a new way of life for the people of developing countries.

In the mid 1960s, an American food company asked Doty to help it find a reliable source of *Eucheuma*, a red alga from which the food and drug additive



Dr. Maxwell Doty in his laboratory.

—Sea Grant photo

carrageenan is extracted. Carrageenan, an odorless, tasteless gel, keeps ground beef juicy while reducing its fat content; acts as a cohesive agent in non-oil based cosmetics, toothpaste and shampoos; and gives body to ice cream and frozen yogurt.

Doty recommended that the company, Marine Colloids Inc., explore the rural Philippines, Micronesia, and other Pacific island nations, because these areas have ideal tropical climates for growing *Eucheuma* and low-cost labor forces for collecting and drying the plant for export.

However, food companies could not depend on these wild crops for consistent harvests. Doty and his team of researchers began working in the Sulu region of the Philippines with local farmers to find a way to domesticate the plant. With the help of his old friend and researcher Vic Alvarez and the farmers themselves, Doty was able to culture *Eucheuma* and create a system for its efficient cultivation.

"Farming of *Eucheuma* looks simple, but it took six years of study and experimentation to develop," Doty said.

Alvarez headed the field operation that Doty directed from his office at the University of Hawaii in Honolulu.

"Vic implemented the things we dreamed up," Doty said. "He started his own farm near Manila where we would work on finding new ways to improve productivity. We came about some of our major breakthroughs there," Doty said.

When Doty and his colleagues later domesticated another species of algae similar to *Eucheuma*, Doty named it *Alvarezii* in honor of the significant contributions made by Alvarez.

Marine Colloids Inc. hired Alvarez to manage its operation in the Philippines, and Doty secured funding from Sea Grant and other national science organizations to continue studying the potential of *Eucheuma* and *Kappaphycus*.

"I had money only for experimentation while Vic had money to buy the seaweed and develop the market," Doty said. "My relationship with Vic helped to raise our work above an academic exercise only."

Doty and his team of helpers in the Philippines next launched a dedicated effort to convince the skeptical

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inhabitants of a coastal village near Cebu in the southern part of the country of the potential of this new industry. He envisioned *Eucheuma* as a cash crop for the impoverished villagers. His team used an incentive system to coax the reluctant villagers into the business of gathering and growing *Eucheuma*.

"It was difficult at first because this class of people didn't trust anybody. They are a very independent people," Doty said. The people had been taken advantage of several times in the past, Doty said, and had grown weary of new people with new ideas.

Once word got around that seaweed farming was a profitable business, Doty's team soon had several willing volunteers. "They invited us into their homes," Doty said. "They knew we were working for the people. We were the only ones other than smugglers bringing money into that part of the world."

Doty's team set up demonstration farms to show the people how to grow the plant in shallow water along uniform rows of monofilament fishline. With this simple and efficient method, the plants doubled in size each week. After a few false starts, several villagers had successful farms.

"One result (of the success) is that people start sending children to school for the first time, or the wife gets her first

new dress or the farmer buys a motor for his boat," Doty said.

In the early 1970s they introduced this seaweed farming method to a community in the southern Philippines of about 3,500 residents. In less than 10 years, more than 35,000 people had moved into the area and were being supported by the seaweed farming industry.

Dr. Celia Smith, associate professor of botany at the University of Hawaii, counts Doty's accomplishments in the Philippines as a major contribution to the field of phycology and the seaweed colloid industry.

"In the farming of carrageenan, Doty was clearly ahead of his time. It is a complicated process to cultivate a plant for the first time. His efforts allowed that industry to mature rapidly by giving it a stable product," she said.

"His work benefited a whole class of people who might have had little hope of economic improvement other than through production of seaweed crops," Smith said.

The industry took off in the 1970s and by 1990, the Philippines was earning \$50 million annually from carrageenan exports, according to the agricultural trade section of the Philippine Embassy in Washington. With the success of new carrageenan-based products, such as the McDonald's Corp. McLean Deluxe

hamburger, Philippine exports of *Eucheuma* were projected to top \$100 million in 1992.

At its height, the Philippines produced 95 percent of the world *Eucheuma* supply, Doty said. But the success of the industry attracted the attention of Philippine political and business leaders. He said the industry "suffered under the Philippine conditions of business," which sent it on a steep decline. Food companies began to limit their operations in the Philippines and move to countries with more hospitable conditions. Today, the world carrageenan market is growing based on thriving operations in Micronesia, Tanzania, and other tropical countries, Doty said.

Doty had a hand in the introduction of *Eucheuma* farming in those and other countries in the central Pacific, Asia, and Africa. He concentrated on labor-intensive, family-sized farms that provide direct socio-economic benefits to people below the poverty line in coastal communities. Besides securing funds from Sea Grant and various private companies, he has received support from the states of Hawaii and Malaysia, Indonesia, the United Nations Food and Agriculture Organization, and its Development Program via the South China Seas Fisheries Development Program.

Doty sees marine agriculture as one of the tools essential to the economic independence of several nations. He estimates a country would have to make an initial investment of \$1.5 million to develop a seaweed farming industry.

"That \$1.5 million is the ballpark figure for the research and development cost of the farming used for *Eucheuma*, which grosses about \$60 million a year," Doty said.

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Sea Grant Investigates... Green-bubble algae

by Adrienne Garnier

Favorable conditions for the troublesome green-bubble algae still exist in Kaneohe Bay. This native species of macroscopic algae has plagued Kaneohe Bay for the past 30 years and evolved from a regular to an overabundant inhabitant within the reef slope community. Dr. John Stimson, a University of Hawaii Sea Grant researcher, is working on pinpointing reasons for the continued success of the algae.

To do this, Stimson and his team are collecting and examining the green-bubble algae, *Dictyosphaeria cavernosa*. In their studies, they will determine the levels of nutrients, such as nitrogen and phosphorous, that the algae contains. They will also attempt to make a map of the patch and fringe reefs within Kaneohe Bay showing locations where *D. cavernosa* has been measured and tested.

The map will be used to determine the possible reasons for the growth of the algae. These may include high nutrient levels due to sewage outfall and stream runoff, amounts of subsistence fishing that affect the grazer fish population, and the preference that grazer fish have for other types of algae.

Stimson will also examine growth patterns of *D. cavernosa*. One factor that may affect the growth patterns is the algae's ability to store nutrients. *D. cavernosa* may be able to retrieve stored nutrients when there are no other sources available. This may be a reason for its continuous growth, even after the diversion of sewage from Kaneohe Bay.

In the 1960s, *D. cavernosa* was just one of the macroscopic algae that inhabited the coral reef in Kaneohe Bay. The algae got the nutrients it needed for a big growth spurt from the sewage outflow to the bay. Sewage contains phosphorous and nitrogen, nutrients that *D. cavernosa* needs to

grow. This spurt slowed in 1978, when 90 percent of the sewage was diverted. Unfortunately, corals grow well only where there are low levels of nutrients.

However, the diversion of the sewage did not stop the growth spurt of the algae. It still continues to threaten the growth of the coral by growing up and around it, and in some places overgrowing it.

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Stimson will determine whether the abundance of *D. cavernosa* has an effect on coral growth and deterioration. He will also examine any positive outcome its growth might have on the reef environment.

"The algae has already overgrown the coral in some areas. Coral branches have been found with algae growing around them. The branches found are still intact, without signs of erosion. This is an indication that the algae grew faster than the coral, growing up and around it," said Stimson.

According to Stimson, the algae could become too dominant. In an extreme situation, it could overgrow all the patch and fringe coral reefs and eventually reduce coral to a small element in the bay.

If the process continues, the coral could eventually be eliminated. This would have a snowball effect. The feeding grounds for fish that graze along the coral would be eliminated, the fish population diminished, and the reef areas used by some subsistence fishermen would be deteriorated.

Other members of his research team are looking at the effects grazer fish and their feeding habits have on the growth of the algae. "The fish generally prefer to eat algae other than *D. cavernosa*," Stimson said.

Surgeon fish, such as the convict and yellow tang and parrot fish, are the usual

grazers on the coral reefs in Kaneohe Bay. *D. cavernosa* has a unique defense against grazer fish because a mouthful of the algae is mostly fluid.

Each bubble is filled with fluid

although the appearance of the algae is extremely dense. "For the grazers, it is like eating cotton candy," Stimson said. "Instead of a mouthful of air and sugar, the fish get a mouthful of fluid that does not yield a high level of nutrition."

The defense against the fish has to do with the characteristics of *D. cavernosa*. Some forms of macroscopic algae are tall and wavy. *D. cavernosa* is not. In its first stage of growth, it grows between the fingers of coral and looks like a small bubble. As the growth continues, other bubbles form next to the first one. They appear to attach to each other and multiply. Masses of tough bubbles press against each other, deform, and collapse until a solid wall of algae forms. Thus its nickname, green-bubble algae.

"The consistency of the algae is so tough that you could cut a square out of the mass and the empty space would remain intact. A diving weight placed on it wouldn't fall through," Stimson said.

Stimson said an additional threat to the growth of the coral is the chamber that could form under a large growth of algae. This chamber becomes a good environment for sponges and tunicates. Some of these animals bore through the coral and weaken the skeletons. Sponges secrete chemicals that dissolve coral skeletons. Eventually, the weakened skeletons could cause the coral to collapse.

The green-bubble algae continues to grow among the reefs in Kaneohe Bay. As a normal native inhabitant, it is considered a productive part of the reef environment. But because it is currently overgrowing the coral in certain places, it is a threat. ◀

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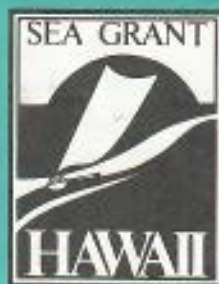
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After half a century of study, Doty has still not satisfied his curiosity about seaweed. Last spring he faithfully attended Smith's Botany 402, a course on the adaptations of plants to the marine environment, every Tuesday and Thursday. Smith, who was a graduate student under Doty in the mid-1970s, found herself in the peculiar position of teaching her former teacher.

"He would sit and listen to my lectures and you could just see the wheels turning," Smith said. "Finally something I would say as an explanation for a phenomenon would click and his eyes would nearly flash."

Doty remembers those moments of inspiration. "It is marvelous what they know nowadays that I should have known years earlier," he said. "In class Dr. Smith explains something that I observed 20 years ago but never understood."

Doty's work at the University of Hawaii began in 1951, when he was lured away from Northwestern University with the promise of a \$6,500 annual salary and a new microscope. Doty said UH attached one catch: he had to devote one third of his time to research. For Doty, who was weary of the "politics and pressures of a big city university" and already curious about algae of the Pacific, it was an offer he could not refuse.

"I decided I would come out here, just look at the algae and enjoy life," he said.

He discovered that Hawaii is home to several hundred species of aquatic plants. However, no one had taken the time to classify and name the majority of these species, making research extremely difficult.

"It sounds simple but it's fundamental," Smith said. "Without that kind of documentation, the exercise is incomplete, so Dr. Doty had a monumental effort to simply document what we have as resources here in Hawaii."

Doty spent years in the field collecting samples into a permanent record of native Hawaiian aquatic plants. His collection filled 17 closets in the Botany department

hallway until he donated the bulk of it to the Bishop Museum in the early 1980s.

Doty made his mark at the University of Hawaii in other ways, too. He developed and taught the "Introduction to Science" course, which later became the core of the general science department. Within three years, the popular course outgrew the botany department. The university had to rent the Varsity Theater on University Avenue to accommodate more than 1,500 students who enrolled in the course.

When asked about his other contributions to the university, Doty holds up his hands and says, "This building." In the plans for a new biology building, the botany department was allotted only two rooms. As chair of the botany department, Doty spent the next year trying to secure funds for a facility devoted to plant sciences. He credits the six-floor Plant Science Building with enhancing the international reputation of the university and for attracting professional and scientific organizations to symposiums held at the University of Hawaii Manoa campus.

Doty holds memberships in dozens of international scientific organizations. He has served as a Fellow to the American Association for the Advancement of Science and as the chair of the International Seaweed Association for two consecutive terms, and has traveled to more than 40 countries for professional research and presentations.

"His international reputation and activities helped put the university on the map for botany," Smith said.

The impact Doty has made on the University of Hawaii and the field of science can also be measured in the quality and caliber of the students who have studied under him. The formidable reputation of his program helped to attract an international array of students who went on to highly visible positions in institutions around the world. Among his more than 30 graduate students, one went on to become the chair of botany at the Smithsonian Institution, another developed the Australian Institute of Science, and another serves as the chair

Watch out for this marine organism:

Microcoleus lyngbyaceus (Limu)



Description: This fine, filamentous blue-green alga, which is often dark green or blackish green, is commonly found tangled with other seaweeds on reef flats, in tidepools, or in deeper subtidal habitats. It can be carried by waves into swimming areas, notably Laie and Kailua on Oahu and other windward areas, and often forms floating masses on the surface of Kaneohe Bay.

Symptoms/injuries: When fragments of *Microcoleus lyngbyaceus* lodge inside swimmers' suits, they can cause minimal to very severe inflammation of the skin, even if the person affected is not allergic to the alga.

Treatment: A swimmer who has been exposed to this blue-green alga should wash the affected area immediately with soap and water and change swim suits.

Preventive measures: Swimmers who are allergic to the alga should stay out of the water when it is present in large quantities.

Excerpted from *Dangerous Marine Organisms of Hawaii*, UNH-SEAGRANT-AR-78-01.

of marine ecology at the Catholic University in Santiago, Chile.

"In some ways he was hard on his students," said Smith. "But potentially that made him one of the reasons why some of them achieved the high levels they did. They got as driven as he was, by one mechanism or another."

Doty relishes his time as a teacher. "You don't really learn a subject until you've taught it. It finally becomes clear to you in all sorts of ways you had not realized before," Doty said. "Teaching is the thing that keeps you alive." ◀

Commercially cultivated *Gracilaria* in Hawaii

by Jennifer M. Ybarra

Seaweed or *limu* — what is the difference? In Hawaii, *limu* has been loosely defined as an edible seaweed. Eating *limu* has been a custom for centuries, but only within the last 10 years has *limu* been grown for commercial purposes in Hawaii. Among the many types of *limu* here, *Gracilaria*, a macroalgae, is the most often commercially cultivated.

Limu (also called *ogo*) needs sunlight to grow, and that is what makes Hawaii one of the best places for growing *limu* — its position near the equator and the ample sunlight it receives. One advantage of culturing seaweed rather than fish is that instead of buying feed, the only thing you need is sunlight and nutrients, explained aquaculture specialist Paul Olin.

There are three seaweed farms on Oahu, two farms on the Big Island, and one farm on Molokai. Royal Hawaiian Sea Farm Inc., located at Keahole Point, on the Big Island, began commercial production of *Gracilaria*, *Porphyra* (*nori*), and *Enteromorpha* (*limu* 'ele 'ele) in 1987. Royal Hawaiian Sea Farm produces several varieties of *Gracilaria*, a long, thick, red strain; a long, thick, brown strain; a short, brown strain; and the red and green *G. tikvahiae*. "The product is clean and ready to use," said Steve Katase, the farm's president. All *limu* considered, the farm consistently produces over a ton a week, and sells most of the *limu* within the state of Hawaii, although some is sold to the mainland.

In Kona on the Big Island, Uwajima Fisheries Inc. markets a long, brown *ogo*, a species of *Gracilaria*. Manager Ryan Murashige said that their product is similar to that grown in its natural state. Uwajima Fisheries is relatively new on the market, considering it just started marketing their product in April of this year. "It's nice the way everything is working out for us — so far it's going good — the market is competitive but the business is good," Murashige said. It sells 700 pounds of *limu* per week and in

December, Uwajima Fisheries will be selling roughly 1,700 pounds of *limu* per week. Unlike Oahu, where the *limu* grows better in the summer months, Uwajima Fisheries has noticed that in Kona, the *limu* is more productive in the winter.

A farm in Kahuku on Oahu, Aurea Marine, is cultivating the red algae *Gracilaria tikvahiae*, producing 400 pounds a week. "Prior to the 1991 flood, we were producing 1,500 pounds a week, but the flood wiped everything out...the market fluctuates but it usually stabilizes between 1,200 to 1,500 a week," said Terry Astro, president of Aurea Marine. "No chemicals are used at the farm — it's all natural," Astro said. Aurea Marine, which began commercially cultivating *limu* in 1986, is presently using a basket culture method to grow *limu*. The *Gracilaria* is put in large baskets that float in long raceways along with fish. The fish are fed, the fish fertilize the water, and the *ogo* grows off the nutrients, explained Astro. The seaweed is sold to Suisan International, a seafood distribution company based in Honolulu.

Hawaiian Marine Enterprises, another farm in Kahuku, is also growing *Gracilaria tikvahiae*. This algae grows well in tank cultures, hence, the farm uses the tumble culture method. This method uses aeration to tumble a large number of plants in a small area, allowing the plants equal access to sunlight. The farm, which began its operation in 1983, produces roughly two tons of *Gracilaria* a week during the summer; however, production goes down 30 to 50 percent in the winter. The *limu* is sold to retailers, wholesalers, and some is exported to the mainland.

At He'eia Fishpond north of Kaneohe, Pacific Aquaculture is also cultivating *Gracilaria*. Mark Brooks, owner of the company, uses the pond culture method for growing the *limu*. Brooks sells the *limu* to seafood stores, restaurants, and two distributors who take the *limu* to local markets. "I don't aggressively market it," Brooks said, because he is only trying to maintain the thrust in restoring the fishpond, which is his primary goal.

"The market is limited right now," he said. "The *ogo* market is significant but not huge, so a few farmers can supply the existing market." Brooks was quick to point out that creating a new market for seaweed is not easy. "If we could get the mainland to start buying the *limu*, we can expand a lot, but that is an educational process," he explained, in terms of getting people to eat *limu* who have never eaten it.

The Molokai *Limu* Project, sponsored by a non-profit organization called Ke Kua'aina Hanauna Hou, has been cultivating *Gracilaria parvispora* on Molokai for the past two years. Although it also cultivates *limu*, the main purpose of the organization is to establish an ongoing community based economic program suited to the resources and lifestyle of the small island rural community.

The Molokai *Limu* Project is trying to create their own seed stock of long *ogo*, so they can have an ongoing supply. The *limu* is cultured using the spore method. Spores are settled onto pebbles in a special hatchery set-up on the land. The pebbles are transferred into a lagoon for growing out to harvest size. "We're trying to get families involved to give them an additional source of revenue," says Colette Machado, director of the project. All proceeds are shared by the growers.

"I'm looking at Molokai making it in the next decade," says Machado. "Molokai has a small population — about 7,200. It's very rural in nature — no traffic lights, elevators — it's the last of the islands to be impacted by economic development. We're trying to supplement our economy while maintaining the lifestyle we have so the next generation can control the small-scale economics."

"We're involved in a community based economic project that has a goal of producing 2,000 pounds a week of this long *ogo* within the next two years," says Machado. "Our emphasis will be on the production of a 'brand name' of *limu* products, such as Kim Chee and pickled *limu*, rather than just the wholesale market." ◀

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If the process continues, the coral could eventually be eliminated. This would have a snowball effect. The feeding grounds for fish that graze along the coral would be eliminated, the fish population diminished, and the reef areas used by some subsistence fishermen would be deteriorated.

Other members of his research team are looking at the effects grazer fish and their feeding habits have on the growth of the algae. "The fish generally prefer to eat algae other than *D. cavernosa*," Stimson said.

Surgeon fish, such as the convict and yellow tang and parrot fish, are the usual

grazers on the coral reefs in Kaneohe Bay. *D. cavernosa* has a unique defense against grazer fish because a mouthful of the algae is mostly fluid. Each bubble is filled with fluid although the appearance of the algae is extremely dense. "For the grazers, it is like eating cotton candy," Stimson said. "Instead of a mouthful of air and sugar, the fish get a mouthful of fluid that does not yield a high level of nutrition."

The defense against the fish has to do with the characteristics of *D. cavernosa*. Some forms of macroscopic algae are tall and wavy. *D. cavernosa* is not. In its first stage of growth, it grows between the fingers of coral and looks like a small bubble. As the growth continues, other bubbles form next to the first one. They appear to attach to each other and multiply. Masses of tough bubbles press against each other, deform, and collapse until a solid wall of algae forms. Thus its nickname, green-bubble algae.

"The consistency of the algae is so tough that you could cut a square out of the mass and the empty space would remain intact. A diving weight placed on it wouldn't fall through," Stimson said.

Stimson said an additional threat to the growth of the coral is the chamber that could form under a large growth of algae. This chamber becomes a good environment for sponges and tunicates. Some of these animals bore through the coral and weaken the skeletons. Sponges secrete chemicals that dissolve coral skeletons. Eventually, the weakened skeletons could cause the coral to collapse.

The green-bubble algae continues to grow among the reefs in Kaneohe Bay. As a normal native inhabitant, it is considered a productive part of the reef environment. But because it is currently overgrowing the coral in certain places, it is a threat. 