Malama Kai *Care for the Sea*

Issue II 1994

Sea Grant: Breaking New Ground

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Sea Grant: Breaking New Ground

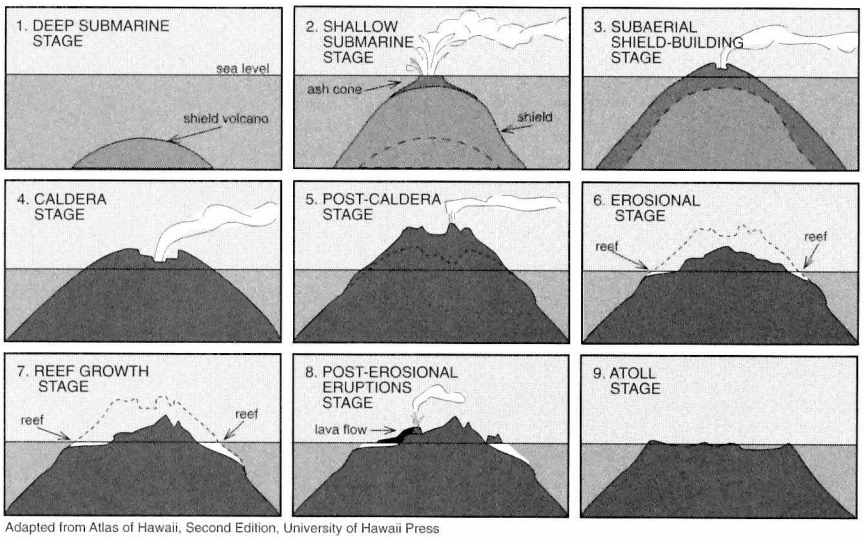
Table of Contents

Sea Grant, a unique partnership with public and private sectors combining research, education, and technology transfer for public service, is the national network of universities meeting changing environmental and economic needs of people in our coastal, ocean, and Great Lakes regions.

The University of Hawaii Sea Grant College Program, directed by Jack R. Davidson, was established in 1968. Its mandate is to promote the wise use and greater understanding of our nation's marine resources through research, education, and extension services. UH Sea Grant supports numerous research projects, an extension program, and a communications unit.

Research Unlocks Ocean Treasures

Nearly 80 million years ago, a fountain of molten rock spurted through the bottom of the ocean near South America's west coast. Like toothpaste slowly being squeezed from a tube, the magma crept from the earth's mantle to the ocean floor, where it began the land-building process of piling, cooling, hardening, then piling up again, according to the whims of the hot spot that fueled the seamount's growth.



Adapted from Atlas of Hawaii, Second Edition, University of Hawaii Press

A chain of islands that extends from the Big Island to an area northwest of Japan (between the Kamchatka Peninsula and Aleutian Islands) was probably fueled by the same hot spot in the bottom of the Pacific Ocean. The chain is made up of the Hawaiian Islands, the Northwest Hawaiian Islands, and the Emperor Seamounts. Cross Seamount was not built by the same hot spot. It developed from a hot spot near the South American Coast.
Seamounts are the result of two phenomenons. Some seamounts, such as the Emperor Seamounts, were actually islands that became so old that they re-submerged into the ocean after the atoll stage. Other seamounts, like Cross Seamount, passed over the hot spot before progressing beyond the deep submarine stage.

Several million years after the birth of the seamount, but before it rose above the ocean's surface, it fell victim to plate tectonics. It traveled away from the hot spot as the earth's plates spread from the East Pacific Rise, an axis along the sea floor, and its growth was halted. The Pacific plate upon which it rode acted like a conveyer belt and carried it toward the northwest.

The journeying seamount became a nest on which marine forms could converge, live, and die. With age, the Pacific plate slowly sank, resulting in the sleeping volcano's descent into the deep sea. Signs of chemical, geographical, and temperature changes are still evident on it, forming distinct layers of time like pages in a history book.

Today, the seamount is marked by cartographers as Cross Seamount and by scientists as one of many Pacific seamounts that are a treasure trove of valuable metals. During periods of volcanic activity, chemicals bound up in marine rocks and sediments were leached and recycled. With the passage of time, the seamounts became imbedded with deposits rich with valuable metals such as cobalt, nickel, and platinum. These deposits are called ferromanganese crusts.

Researchers and state leaders are especially interested in the cobalt in the crusts. Cobalt is an economically important metal

because it is used extensively by the aerospace and manufacturing industries to make cutting tools, drill bits, permanent magnets, turbine blades, and high-speed tools. Cobalt is also used in computer hard disks, and audio and video tapes. The United States is the world's largest importer and consumer of cobalt.

"Seamounts could possibly supply the United States with all of its cobalt needs," said Dr. John C. Wiltshire, a Sea Grant researcher who is encouraging land-based mining companies to cast their eyes on the ocean's mining potential.

"However, detailed mapping of the ferromanganese crust fields will be required to document the metal grades and continuity of this vast resource," Wiltshire added.

A sponge and coral grow among the ferromanganese crust on Cross Seamount. –courtesy of R. Grigg

Beginning the Search

The University of Hawaii's newest research vessel Ka'imikai o'Kanaloa *is specially designed for marine minerals research. –J. Ybarra*

In 1989, a team of 10 investigators in the UH Sea Grant Ocean Minerals Program boarded research vessels armed with high-tech surveying equipment, determined to shed some light on the puzzling ferromanganese growth. They included Dr. Alexander Malahoff, Dr. Fred T. Mackenzie, Dr. Jane S. Tribble, Dr. Gary McMurtry, Dr. Eric H. De Carlo, Dr. Hsueh Wen Yeh, Dr. Gordon Taylor, and Dr. James P. Cowen of the UH oceanography department; Dr. Barbara H. Keating of the Hawaii Institute of Geophysics; and Dr. John C. Wiltshire of the Hawaii Undersea Research Laboratory. Their destination: Cross Seamount.

"The only way we can know where to find the ferromanganese crusts is by first understanding how they grow," explained Malahoff, an oceanographer and geophysicist. "This information is important because before we can even begin trying to mine them, we have to know where to look."

Because Cross Seamount is located only a day away from the island of Hawaii by ship and within the United States' Exclusive Economic Zone (EEZ), it is the ideal underwater laboratory for researchers to examine the distribution of minerals and determine the possible effects of ocean mining on the environment. Cross Seamount is also a classic site for researchers to study because it is far away from submerged sand banks, making it virtually uncontaminated by shallow water sediments.

Malahoff, who directed the expedition, studied the chemical composition changes and geology of the crusts by examining the seamount layer by layer.

"Stratigraphy holds so many answers," Malahoff said. "The stratigraphy of the ferromanganese crusts reflects the geological history of the seamounts. It also tells us the chemistry of the Pacific Ocean, through which the seamounts traveled on their 8,000 kilometer journey.

"Chemical changes are affected by time and water depth. We can understand what happened, when it happened, and where it happened by studying the crust's layers."

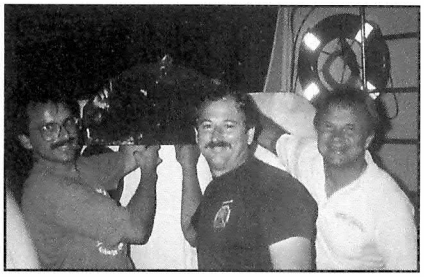
Each of the researchers analyzed and scrutinized possible criteria for ferromanganese growth. Later, scientists pooled their results for a more accurate interpretation of the ocean's geologic history.

Keating, a morphologist and geophysicist, returned with geological maps of the seamount's summit and rift zones through submersible dive programs. Oceanographers Cowen and Taylor studied the microbiology of the ferromanganese crusts.

Tribble, a sedimentologist and geophysicist, and Mackenzie, who is a geochemist, combined their skills to document how the waters of different carbonate chemistries, pH, temperature, and oxygen content affect the sediments and rocks.

Looking Ahead

Although results were often complicated by the effects of erosion and mass wasting, the 1989 expedition brought a greater understanding of



David Karl, Gary McMurtry, and Alexander Malahoff hold a metal plaque that is covered with iron-oxidizing bacteria after being deployed at Loihi for six months. –courtesy of G. McMurtry

ferromanganese growth. And, like all good scientific experiments, it raised new questions.

What specific environmental conditions are important in the formation of cobalt deposits? How fast do ferromanganese crusts grow? What are the criteria for crusts with the highest ore-grade potential?

"Following the expedition, projects mostly were designed to predict optimal depths and environmental conditions for crust formation and improve exploration methods," Cowen said. "This would lead to cost-savings during exploration and exploitation of cobalt-rich ferromanganese crusts."

Scientists also began examining the crusts to see if the ferromanganese could have other uses, thereby increasing its value. Dr. George Andermann, a UH chemist, is attempting to convert the manganese crusts into useful electrical and magnetic material. The type of crust, which Andermann is calling "Black Hawaiian Beauty," has unique impedance (electrical resistance) properties.

Wiltshire's team is experimenting with a variety of products made from ocean mining wastes (tailings). Products include tiles, glass, coatings to resist rust and biofouling, spray coatings, drilling mud, concrete additives, and soil amendments for agriculture.

"If we can use manganese tailings for useful products, they will help to prevent environmental degradation and

Researchers are hopeful that ocean mining wastes will be used for a variety of products, such as this artistic tile. –S. Magaoay

John Wiltshire holds a turtle made from ocean mining wastes. –S. Magaoay

improve the economic outlook for mining," Wiltshire said.

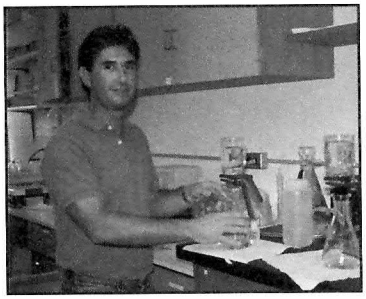
With the growing body of evidence that ocean mining is feasible and potentially lucrative, Sea Grant researchers are beginning to develop underwater mining methods. Working with Malahoff, graduate student Kimo Zaiger is developing a unique and relatively environmentally-safe way to mine and leach the minerals *in situ* on the sea floor around Johnston Island, where the deposits with the largest and highest grade of cobalt in U.S. waters have been found.

Completing the Puzzle

Meanwhile, Malahoff is continuing to piece together a picture of what has taken place on the seamounts over the past 80 million years. Researchers are sampling and mapping the crust pavements to test hypotheses that will help to explain the size and content of cobalt-rich ferromanganese crusts.

Malahoff is working with results obtained by oceanographer McMurtry and geochemist De Carlo to develop a more exact model of how crusts accumulate. The model will be used to predict crust distribution on other Pacific seamounts.

"We're convinced that the growth of the ferromanganese



Eric De Carlo analyzes imprints in his lab to date the ferromanganese crusts. –S. Magaoay

metal-rich crusts is related to the chemical history of the Pacific Ocean," McMurtry said. "We're analyzing the crustal layers to see what has happened over the centuries. We're also lucky to have Loihi. It's helping us to see the beginnings of a seamount and compare our predictions."

In addition to using chemical stratigraphy, De Carlo is using biostratigraphy to date the crusts by looking at imprints and skeletal remains from a variety of organisms found in the layers of ferromanganese crusts.

"Ferromanganese oxide replaced the original 'bugs' as they dissolved away," De Carlo explained. "This effectively left an imprint, or mold, of the original organism's skeleton."

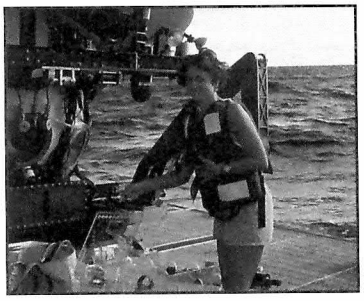
De Carlo uses these imprints to identify the organisms. Often, these organisms lived during a specific time period and researchers are able to pinpoint the age of the crust according to the type of organism found.

Part of oceanography graduate student Miriam Bertram's project includes looking at one way that coccolith imprints are formed. A coccolith is a calcified scale that covers the remains of coccolithophorids, a type of algae. These coccoliths become templates on which ferromanganese minerals are deposited.

"We're trying to understand what kinds of organisms affect the growth and composition of the ferromanganese crusts," Cowen explained. "The results will provide a baseline for interpreting the results of stratigraphic techniques for dating crusts and estimating their growth rates."

Bertram and Cowen have placed numerous mineral plates on the ocean floor at four different depths. Microorganisms and mineral deposits accumulate on these two-centimeter-by-two-centimeter plates. Later, they retrieve the plates and study the microorganisms under a scanning electron microscope, which has the power to magnify a specimen over 10,000 times.

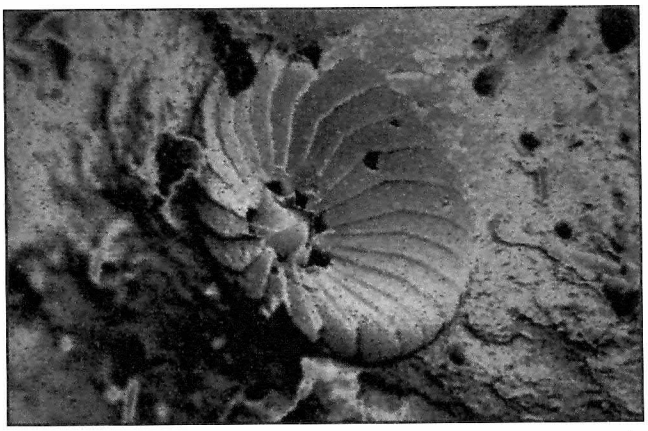
The pieces of the ferromanganese puzzle are falling into place. Researchers have collected enough samples from different seamounts to begin correlating their stratigraphy and mineralogy.



Miriam Bertram prepares to deploy trays of small plates on which microorganisms accumulate and minerals deposit. – courtesy of M. Bertram

"We can now see if there is any consistency in the stratigraphic record from one site to another, or from one seamount to another," Malahoff said. "We have to take into account geological processes, such as slumping, sliding, and stacking, but soon we will have a model that can be used to predict where the thickest and most continuous crusts can be located."

Mining in Hawaii — a state with limited land resources — would have sounded impossible several years ago. But as researchers slowly piece together the ferromanganese mystery and begin to make sense of the ocean floor's stratigraphy, a booming cobalt industry in the islands may be on the horizon.



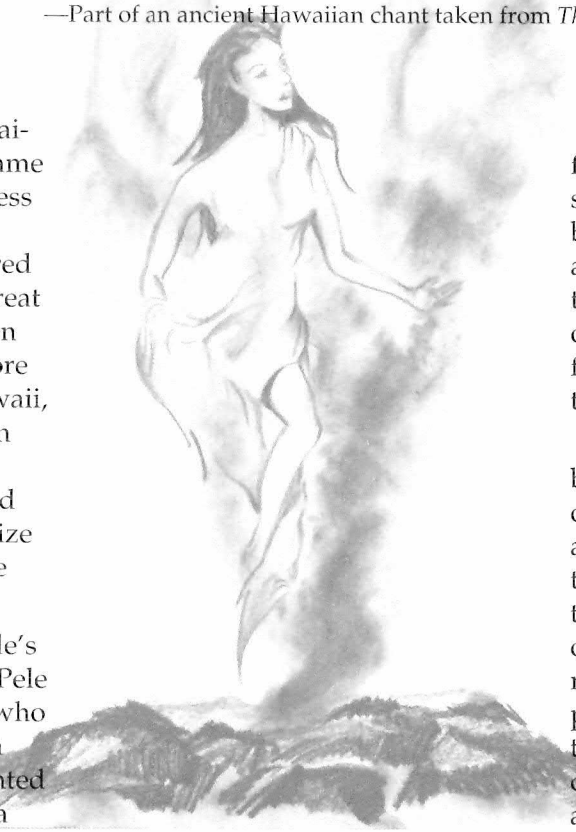
A calcified scale remains after the original algae, a coccolithophorid, has dissolved. Eric De Carlo studies these because ferromanganese minerals deposit on them. –courtesy of E. De Carlo

Loihi, the Legacy of Pele

Embryonic Island Gives Researchers Unique Opportunities

The god is at work in the hills;
She has fired the plain oven-hot;
The forest-fringe of the pit is aflame;
Fire-tongues, fire-globes, that sway in the wind —
The fierce bitter breath of the Goddess!

—Part of an ancient Hawaiian chant taken from *The Water of Life*, by Rita Knipes



According to Hawaiian legend, Madame Pele — the goddess of fire — was a beautiful, passionate, but fiery-tempered woman who commanded great respect and fear. She lived on Kauai, Oahu, and Maui before settling on the island of Hawaii, where she made her home in Kilauea Crater. Legendary evidence of her existence and power continues to mesmerize and humble all who visit the still active volcano.

According to L.K. McBride's book, *Pele, Volcano Goddess*, Pele married Kamapuaa, a man who could also take the form of a pig. Although their love lighted the top of the mountain for a long time, the romance eventually began to flicker.

One day, after a heated argument, Pele's irrational rage ignited and she drove her husband away from the mountain top with burning words. Years later, Pele regretted the break-up and asked Kamapuaa to return to Kilauea and be her husband again.

But Kamapuaa refused, saying, "It's true that you have a warm heart, Pele. But you have a fiery temper as well, and I want no more with you."

Pele still tried to fan the embers of their former love. "Someday," she promised, "I will build for us a new island, a new land in Hawaii, and there we will live together in harmony forever."

Today, Pele's vow is being fulfilled. Twenty-one miles southeast of Kilauea, 3,000 feet below the surface of the sea, is a volcano that is rising more than 15,000 feet above the ocean floor. It has another 3,000 feet to grow before breaking the ocean's surface.

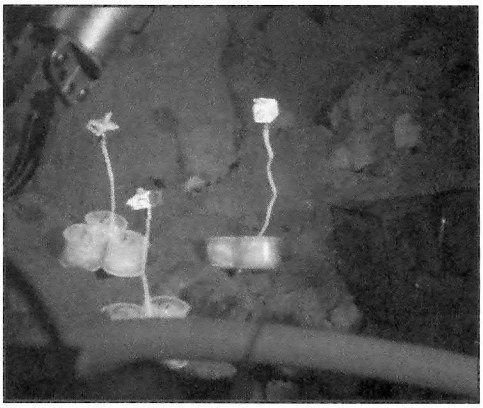
Loihi, which is estimated to be about half a million years old, was previously considered a dormant volcano. But in 1950, the Hawaii Volcano Observatory recorded volcanic activity on Loihi. UH Sea Grant researchers have been amazed, puzzled, and delighted with the host of experiments being conducted at the unique and accessible embryonic island.

"For the first time, we are able to witness an island being born," said UH Sea Grant oceanographic researcher Dr. Alexander Malahoff. "It can help us to understand how the Hawaiian Islands were formed millions of years ago."

In addition to answering age-old geology questions, the mysteries of geochemistry, mineralogy, microbiology, physiography, and ecology have also begun to unfold since Loihi's revival.

The hydrothermal vents have been especially fascinating. A hydrothermal vent is a spot where hot water from the cooling magma breaks through the ocean floor into waters of near-freezing temperature. The vents are rendezvous points for minerals, chemicals, and mantle-derived gases that usually do not interact with each other. The result of this dynamic setting is an environment that hosts some bizarre life forms that can live without the sun's life-giving photosynthesis and in temperatures ranging from 30 degrees Celsius to boiling point (100 degrees Celsius).

Most known hydrothermal systems are found at or near tectonic plate boundaries. But through data derived from dredging, near-bottom water sampling, seafloor camera surveys, and submersible dives, UH researchers confirmed that two hydrothermal fields were present at the summit of Loihi. Researchers named them Pele's Vents and Kapo's Vents (named after Pele's older sister).



A submersible's mechanical arm lays bacterial traps on sulfur dioxide microbial mats found near Pele's Vents. David Karl and Craig Moyer study the trapped bacteria to determine their evolutionary history. –C. Moyer

Loihi's hydrothermal vents are different from other known vents because there is no luxuriant macrofauna, the fluid chemistry is unusual, and microbial processes seem to be dominated by iron-oxidizing bacteria, according to Dr. David M. Karl, a UH Sea Grant oceanographer.

"The iron-sulfur chemistry of the vents is so unique that we think the habitats found there are different from any others ever studied," said graduate student Craig L. Moyer. "So far, over a dozen bacteria have been discovered. None of these bacteria are exact matches to those reported in any culture collection. This means they are probably only found on Loihi. Our understanding of microbial biodiversity has increased significantly because of Loihi."

Sea Grant researchers have found orange-colored bacterial mats up to several feet thick growing on the lava. Scientists watch these iron-rich bacterial colonies grow through deep-sea video monitors until the bacteria colonizes and clouds the camera lenses.

"This is the only place in the ocean where these peculiar bacteria are found. Bacteria similar to this usually exist in strip-mining or other polluted areas where there is a lot of iron," Karl said.

To get a better view of Loihi, which is the only known active underwater volcano in the Hawaiian region, researchers will deploy a permanent ocean-bottom observatory. The Hawaii Undersea Geo-Observatory (HUGO) will give scientists on shore a real-time view of Loihi's volcanic activity through the miracles of fiber optic cable technology. The observatory will be a web of over 20 cameras, sensors, and instruments plugged into a system of fiber optic cables draped across Loihi's summit and slopes.

"For the first time, we can collect long-term, time-series data on the composition of hydrothermal vent fluids," said Dr. Gary McMurtry, a UH oceanographer. "So far, we only have 'snapshots' in time of what's happening and have had to fill in the missing time frames with guesses."

A bathymetric map of Loihi (Loihi means "long and tall" in Hawaiian). –G. McMurtry

To learn more about the composition and evolution of the hydrothermal fluids and mineral deposits, McMurtry is linking a chemical monitoring station to HUGO.

Hydrothermal fluid exiting from Pele's Vents results in unique microbial mats and iron-oxides that form chimney. –C. Moyer

"Most research efforts in the past have studied the composition of seawater, marine sediments, and the ocean crust," McMurtry said. "But not much has been done in terms of the magma chemistry and what goes on below the surface of the ocean."

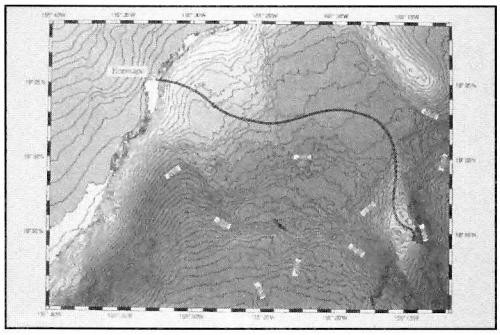
McMurtry is trying to understand the relationship between the composition of hydrothermal fluids and volcanic eruptions. His and other Sea Grant projects will add to the data used by scientists to make earthquake predictions.

"You would be surprised at how many people live on the flanks of active and dangerous volcanoes," McMurtry said. "Not only in other countries but also in the U.S."

Karl's project has taken him over 16,000 feet deep via submersibles to the base of Loihi, in search of hydrothermal vent-water and microbial mat samples that were described by Malahoff during a hunt for hydrothermal vents in 1990.

The project will help researchers outline the types of microbial organisms that live in such extreme environments. Using state-of-the-art molecular biological techniques, Karl will characterize the structure and diversity of microbial communities that are presently difficult to culture. He will also analyze the genetics of microorganisms found at the vents to examine their relationship to other known microorganisms.

The project could also lead to the discovery of "seed stock" for bacteria used in biotechnology because of the bacteria's unique ability to live in high temperatures (see related story on page 11).



HUGO, a permanent ocean-bottom observatory, will be placed on Loihi and linked to shore, giving researchers the opportunity to conduct real-time experiments in this "backyard laboratory." –G. McMurtry

"From an ecological and environmental point-of-view, molecular microbiology is very important because it helps us to find novel species unobtainable through classical microbiological techniques," Moyer explained. "We can see that each of these organisms studied are very important if we want to understand the total biodiversity of our planet."

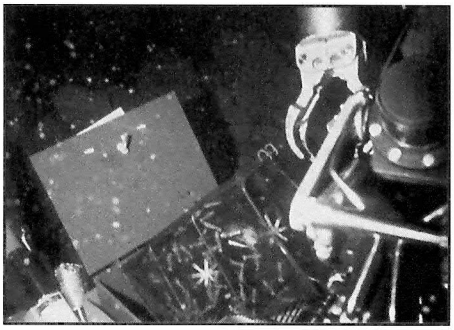
Results of Karl's project will provide the geothermal industry with valuable information on hydrothermal systems. It will also help researchers better understand the processes that produce hydrothermal ore deposits and the environmental consequences of deep-sea mining.

Most importantly, Loihi is helping scientists to understand the "basic fundamental processes" of volcanoes, said McMurtry.

"We can learn how the magma comes out, how it's placed in the crust, what evolutionary processes take place," McMurtry said. "Perhaps, the $64-million-dollar question can be answered: How far down are the magma pools?"

Scientists can only guess how long or how high Loihi will grow. Volcanic activity may halt unexpectedly, stunting Loihi's growth. Or the volcano could erupt suddenly, raising Loihi to the surface sooner than anyone expects. It could surface anywhere from 10,000 to 100,000 years from now.

But whatever time frame Pele decides to follow, Loihi will provide UH Sea Grant scientists with endless research opportunities and a once-in-a-lifetime look at processes that helped create the world.



A new genera of shrimp, which probably live off the microbial mats, were found near Loihi. –C. Moyer

20th Century Undersea Odyssey

Venturing 2,000 meters deep into the silent ocean in the protective confines of a personal submarine, watching rare species of sea life interact anonymously, and drifting into the shimmering waters of an occasional hydrothermal vent, sounds like a science-fiction buff's dream journey.

Modern technology now makes such experiences a reality, but for serious marine scientists, it's not glamorous at all.

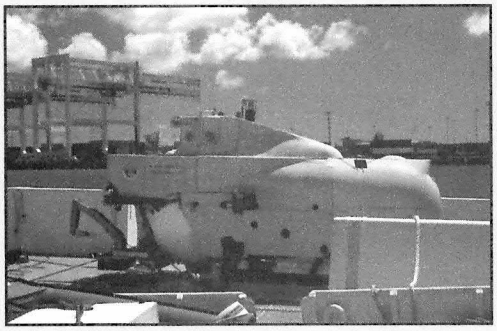
Slightly smaller than a Volkswagon bug, submersibles are battery-powered, one-room research submarines that hold about three people during dives, which can last up to twenty hours. These exploratory vehicles are a vital part of the ocean minerals research projects at the UH Sea Grant College Program.

Submersibles enable scientists to make direct observations, collect samples, take photographic and video recordings, deploy instruments, and monitor the environment.

John Smith, a Sea Grant-funded graduate student working under Dr. Alex Malahoff, said experiencing a submersible dive is exciting because he "gets to see things that no one else will ever see."

From the tiny window, passengers can see a diversity of life forms that exist without the life-giving processes of the sun. Bioluminescent copepods, euphausiids, salps, and colonies of marine snow aggregates float silently by.

But Smith is skeptical of scientists who report glamorous versions of submersible dives.



SOEST researchers use this submersible, the PISCES V, *to explore the ocean floor. –J. Ybarra*

"After 10 to 12 hours of being in it, you just want to get out," Smith said. "A lot of people would be claustrophobic. You're cold, cramped, and uncomfortable. It's dark outside. It's really kind of eerie. It's like driving to Kaena Point (the most western point on Oahu) at night without any lights on."

Dr. Jiro Naka, a visiting geologist from Kyushu University in Japan, said the worst part about the dives is the coldness.

"And if you have to use the bathroom," Naka added, "big problem."

Submersibles are equipped with high-tech video cameras and instruments that measure temperature, depth, salinity, and chemical makeup, but bathrooms are non-existent.

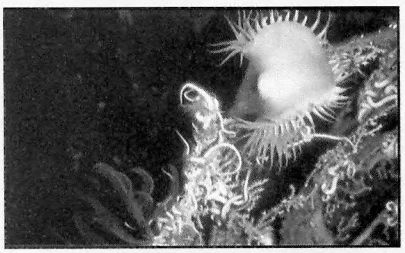
The submersibles also come complete with hydraulic manipulators, or arms, that passengers can use to "grab" specimens and sediment. They have storage baskets to hold these samples and can even collect small, soft-bodied organisms.

"We've seen species that have never been discovered before," Smith said. "Some creatures are so fragile that they can only survive in the deep ocean. We bring them up and they just shrivel up and die. It's kind of sad because they looked so beautiful."

Scientists have been using the submersibles to monitor the birth of what may be the next island in the Hawaiian chain. The dynamics of Loihi's underwater volcanic activity is creating an exciting environment for scientists to conduct innovative experiments.

The University of Hawaii owns two submersibles, the *Makali'i* and *Pisces V*. Biologists, engineers, geologists, geochemists, geophysicists, environmentalists, and fisheries experts from all over the world also use these submersibles to collect data and specimens unique to Hawaii's waters.

Pisces V, a three-person vessel, has a cabin space of about two meters in diameter and can reach depths of 2,000 meters. *Makali'i* is a two-person submersible that is currently not in use. Both submersibles are housed at the Makai Research Pier at Makapuu Point. The Hawaii Undersea Research Laboratory (HURL), a cooperative program between the National Oceanic and Atmospheric Administration (NOAA) and the University of Hawaii, maintains the equipment and assists scientists with their projects.



Actinoscyphia, one of the beautiful organisms found at the bottom of the sea. –G. McMurtry

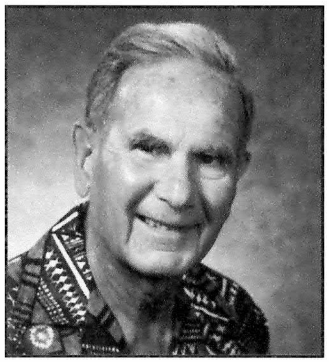
Healing Powers of the Ocean's Organisms

Some of the beautiful sea organisms that delight underwater adventurers are poisonous.UH Sea Grant researchers are learning that these fascinating, yet dangerous, organisms may have possibilities in the medical field. The cure for some of the world's most deadly diseases may be in the ocean, where an estimated 80 percent of all life forms exist.

"Marine biotechnology is an exciting field because of the untapped supply of resources that the sea has to offer," said Dr. Paul J. Scheuer, a UH Sea Grant researcher in the chemistry department and world-renown expert in the field of marine organisms.

Historically, drugs have been developed primarily from flowering plants. Combing forests for species with medicinal potential is logistically easier than searching the vast ocean. Aspirin, for example, was developed from a compound found in a tree bark, and penicillin comes from molds.

But as people are beginning to develop immunity to established drugs, researchers are looking to the ocean as a new source of drug development. The onslaught of new diseases, such as AIDS, and baffling old ones, such as cancer, has also necessitated the need to find



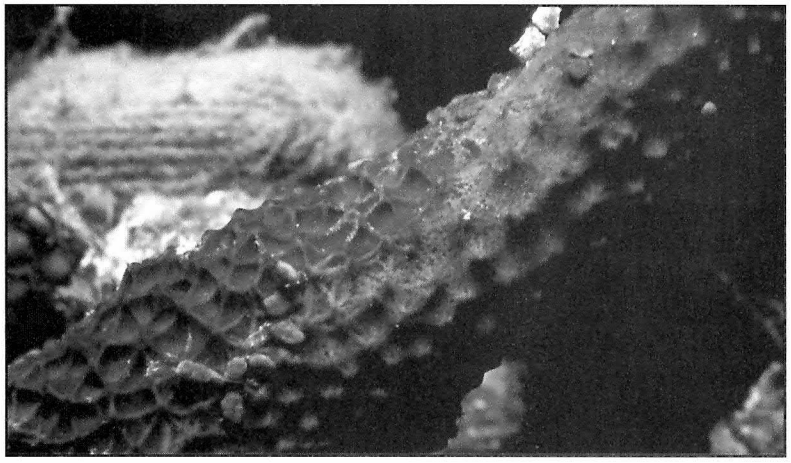
Sea Grant Researcher Dr. Paul J. Scheuer. –Manoa Marketplace Photo Design Studio

new remedies. Fortunately, technological advances, such as submersibles and SCUBA, have made underwater research easier. Today, marine biotechnology is a veritable sea of endless possibilities.

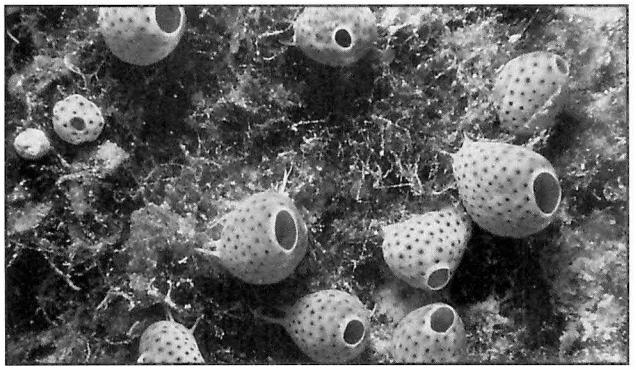
The goal of the UH Sea Grant's Marine Natural Products Program is to identify bioactive marine compounds with pharmaceutical potential and to purify them in quantities necessary for clinical screening. Sponges, soft corals, tunicates, and shell-less mollusks have been of particular interest to researchers because of their unique chemistry.

"They need sophisticated chemistry to stay alive because they are sessile, or slow swimmers, and lack hard shells or spines," Scheuer said. "Their chemical makeup helps them to avoid becoming someone else's dinner."

Scheuer explained that drug development first begins with the isolation of a promising bioactive compound. Scheuer and his team of researchers collect sponges and other



A compound named manoalide, after the University of Hawaii at Manoa, was extracted from Luffariella variabilis. *This sponge has properties that may be effective in combatting arthritis. –P. Scheuer*



Preliminary tests have shown that the Didemnum molle, *a tunicate, has anti-HIV properties. –P. Scheuer*

marine invertebrates in waters around Hawaii and other Pacific islands. Then they evaluate each animal for potentially useful bioactive properties.

"Of course, I don't do too many dives now," the seventy-eight-year-old chemist said with a chuckle. "Trying to control the equipment and collect specimens at the same time can get pretty complicated."

Scheuer confesses that his knowledge of marine organisms was "entirely culinary" when he first began teaching at the University of Hawaii.

"I only knew about the things that you find on the table — lobsters and shrimp," Scheuer said. "I had no knowledge of marine organisms except for what I ate."

Scheuer, who had never even been to an aquarium before moving to Hawaii, said he saw his first sea urchin while snorkeling at Hanauma Bay and was "fascinated by the colors of the shells."

His fascination with the exquisite colors of the urchins led him to a career in organic chemistry of marine organisms that has spanned 40 years, making him a highly respected expert in the field. Scheuer recently received the 1994 Ernest Guenther Award from the American Chemical Society.

In 1980, Scheuer documented the mild microbial activity of a Palauan sponge, *Luffariella variabilis*. The compound was called manoalide, after the University of Hawaii's Manoa campus, where it was isolated.

The medicinal potential of manoalide was later discovered by researchers at the University of California-Santa Barbara and the Scripps Institution of Oceanography. They found that it may be effective against arthritis, bee stings, and other inflammatories. Manoalide is now undergoing clinical testing, but has already proven to be superior to some drugs on the market, according to Scheuer.

Once a lead is discovered, the organism is cultured or the compound is chemically synthesized so that in-depth screening can take place. For the past 12 years, UH biologist and Sea Grant researcher Dr. Gregory M.L. Patterson and collaborater Dr. Richard E. Moore have grown and evaluated more than 1,000 strains of blue-green algae. In addition to testing the algae against AIDS and many types of cancer, Patterson and Moore screen the algae for properties such as antifungal, antiviral, and anti-inflammatory activities.

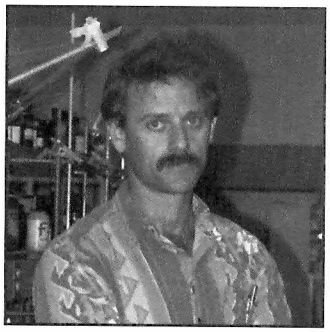
Patterson describes his first encounter with blue-green algae as "love at first sight."

"I was always interested in biology, but I especially love algae," Patterson said. "They're beautiful. They're everywhere."

Patterson is trying to find the most efficient method of culturing this valuable resource. Besides medicinal purposes, algae are widely used in many commercial products. Some types of algae are used in animal feeds, milkshakes, and paints. Blue-green algae, known as cyanobacteria, have compounds that are used in health food additives.

Building on techniques used by scientists to recover active substances from bacteria and fungi, Patterson is attempting to mass produce the algae in glass flasks. The flasks have varying concentrations of nutrients, such as nitrogen, phosphorus, calcium, and iron.

In an effort to develop optimal culturing conditions for marine organisms with medicinal potential, Dr. Gregory M.L. Patterson grows algae in glass flasks in his lab. –Sea Grant file photo



Sea Grant Researcher Dr. Marcus A. Tius –S. Magaoay

Results from his experiments outline the optimal nutritional and environmental conditions for growing algae that still contain their secondary metabolites (compounds that act in self-defense).

"This type of research is important because the future of microalgal biotechnology depends on the development of antibiotics or biomedical research tools," Patterson said. "These are high-value products."

Rather than trying to grow organisms, UH chemist Dr. Marcus A. Tius is attempting to produce compounds with biomedical potential by chemically synthesizing analogs. Analogs are compounds that are structurally similar to the naturally isolated compound. Tius, who is also a Sea Grant researcher, received a lead from scientists in Japan on a soft coral that showed the ability to inhibit tumor growths. The compound, sarcophytol A, was extracted from a soft coral called *Sarcophyton glaucum*.

If the compound does lead to the development of a drug, it would not cure cancer. Instead, the new drug would prevent a person from developing cancer. People who have intestinal polyps, are in remission, or have a family history of the disease would benefit from such a drug, according to Tius.

"Creating completely synthetic analogs of a compound is difficult, but sarcophytol A is a relatively simple molecule, so it's easier to assemble," Tius explained.

People who are in remission, or have a family history of cancer would benefit from this drug

Tius describes the process as "architecture on a molecular scale."

"I guessed what structural element was necessary for the metabolic reaction, then retained it when I assembled the analogs," Tius said.

After preparing four analogs of sarcophytol A, researchers were pleasantly surprised when two of the analogs had the antitumor-promoting activity.

"It was dumb luck," Tius said. "I guessed right. I was lucky."

Tius and his group recently discovered a more efficient method of synthesis and have successfully used it as they've created the analogs.

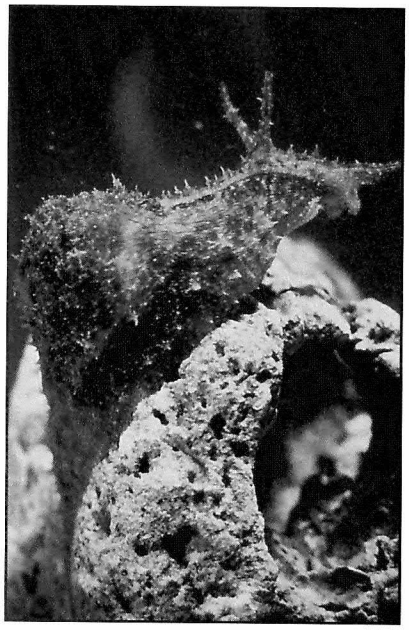
"It (the new method) came about because I was thinking about problems that relate to sarcophytol A," Tius explained. "If you think about something long enough, you begin to see the relationship of the problem to other things that you know. This allows you to devise an optimal solution."

Still, a much more potent analog is needed before drug development can even be contemplated, Tius said.

"I don't want to give people false hope," Tius said. "A drug to prevent cancer is very much possible, but it's not something that will happen soon."

But Tius enjoys the challenge.

"I started chemistry because it wasn't easy," Tius said. "Now I like it because I'm never bored. There are always new problems and so I never run out of things that interest me."



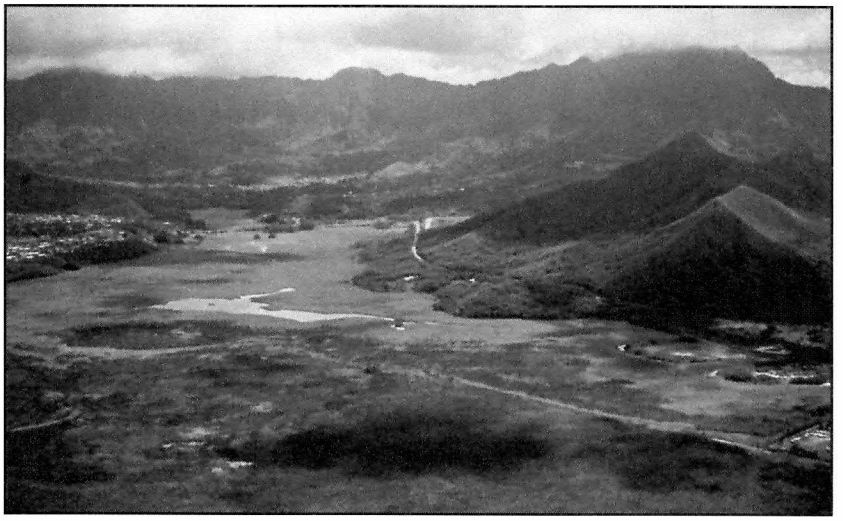
In the future, researchers may use the unique chemical properties of this sea larvae, Stylocheilus longicauda, *to study cancer growth. –P. Scheuer*

Water: The Lifeline of the Land

The ancient Hawaiians considered the Kailua-Waimanalo area a very desirable place to live because of its natural resources. Rich soils, abundant water supply, and mild climate made the native Hawaiians on the windward side of the island a prosperous group of people. They cultivated taro in the valleys and raised fish in the rivers and along the coastline.

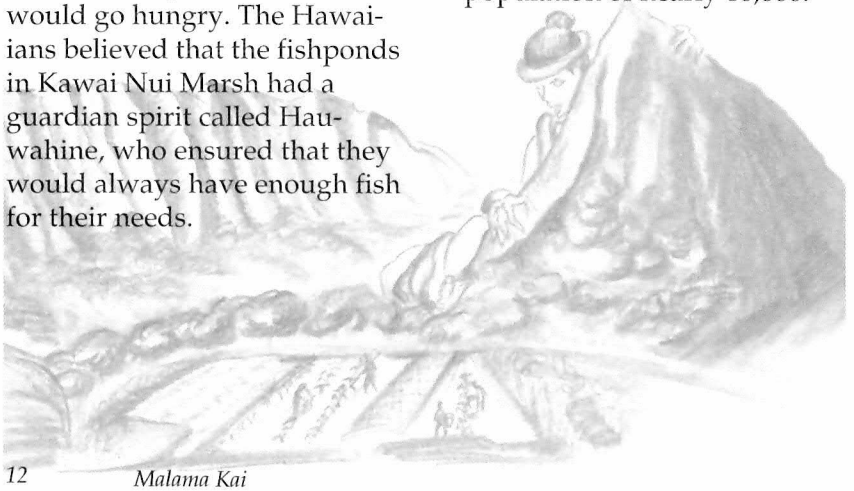
Streams and waterfalls from the Koolau mountains run through the valleys and to the ocean, creating diverse mountain and aquatic habitats in the area. One unique habitat is the Kawai Nui Marsh. Located mauka of Kailua, the marsh is often referred to as the "heartblood of Kailua." The wetland is saturated with as many legends as it is by gallons of water. Each legend is a testament to the area's ability to sustain life in days of old.

Makalei was a famous legendary tree that had the power of attracting fish. Edible mud, or lepo 'ai 'ia, was said to be found in the pond of Kawai Nui, ensuring that no one would go hungry. The Hawaiians believed that the fishponds in Kawai Nui Marsh had a guardian spirit called Hauwahine, who ensured that they would always have enough fish for their needs.



The Kawai Nui Marsh is one of the areas that will be monitored by windward Oahu volunteers involved in the state's water quality monitoring project. –USFWS

But these life-sustaining figures have not been able to withstand one thing: environmental change. As human values and needs have changed, the use of the land has also changed. A rock quarry now operates near the marsh and part of the marsh is used as a sanitary landfill. Golf courses, schools, shopping centers, military stations, and hospitals have been built on Oahu's windward area. Kailua is a bustling city with a population of 53,000. Nearby Waimanalo has a population of nearly 10,000.



The ability of fresh water to sustain and give life is clearly reaching its limits. But the state has been unable to develop a management plan because of the lack of water quality documentation in the area.

In 1993, the UH Sea Grant Extension Service began coordinating a water quality monitoring project in the Kailua-Waimanalo area, including Kawai Nui Marsh, for the State of Hawaii Department of Health. This information will be a valuable asset to the health department in developing a coastal and watershed management plan. The health department will also use the information to enforce water quality standards and achieve the goals of the Clean Water Act of 1972.

"Whatever is going on around the area impacts the marsh," said Susan Miller of the Kawai Nui Heritage Foundation. "The marsh acts as a

filter for whatever comes downstream and into Kailua Bay. So likewise, whatever happens in the marsh impacts the entire bay."

Kailua Bay, like the Waimanalo coast, is used by locals and tourists for a variety of ocean sports — everything from swimming to windsurfing to bodyboarding — making clean water an extremely important resource.

The project will use volunteers from the community to carry out simple water quality sampling and surveys in the coastal zone and watershed. Volunteers began training in February 1994 to conduct field surveys of watershed land uses, streams, and the shore. They were also trained to collect water samples for more in-depth laboratory analyses.

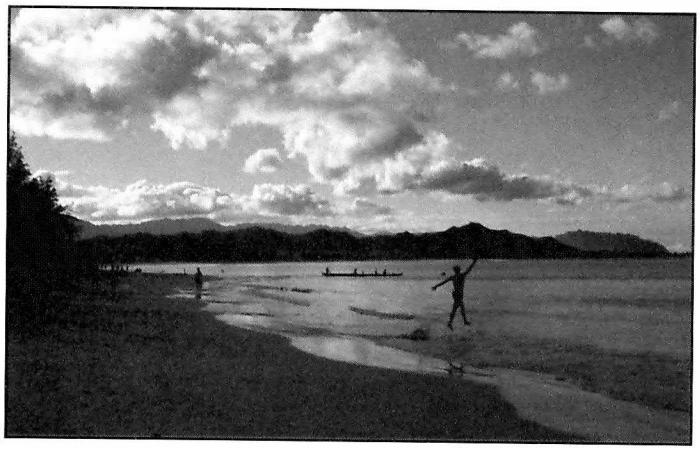
Miller said conclusive studies on the water quality of the area are not available, but through plain old visual observation, the streams, marsh, and ocean are not as clean as they once were.

"There's been a definite increase in erosion and sedimentation into the marsh. "Once I was driving after it was raining pretty hard and saw a thick, brown stream going down the highway. I followed it. It emptied right into the marsh."

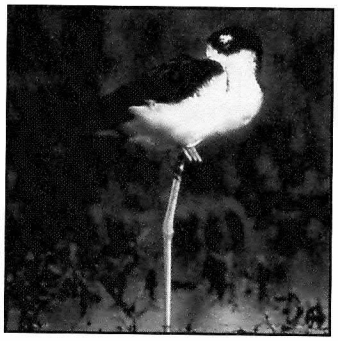
"The volunteer project is a cooperative approach between community members, government agencies, scientists, and private landowners," said David Tarnas, UH Sea Grant Extension Service agent and project coordinator. "It's a cost-effective way to monitor the quality of the water. Volunteers are important because they can be at a site quickly and frequently when an event occurs, such as an algal bloom or rain storm."

The pilot program will be used as a model to develop other volunteer monitoring programs throughout the state. The goals of the water quality monitoring program are twofold: to organize volunteers to collect usable water quality information and to help develop an educated and involved community that is committed to protecting water resources.

"This is a great project for people who want to do something other than clean up the beach. This project gives you more control," said Barbara Volhein, who is a teacher at Kalaheo High School. "When you clean the beach, you just pick up whatever is there. You don't have a way to control the litter. You don't know where it's coming from, so you don't know how to stop it.



Even at dusk, residents and visitors enjoy many activities at Kailua Bay. –S. Kaneshiro



The Hawaiian Stilt, an endangered waterbird, enjoys the quiet solitude at Kawai Nui Marsh. –USFWS

"But with the monitoring program, you get validated data, so you can find out the pollution source, assess the damage and the contributions, and decide if something can be done. You can collaborate on what is or isn't polluted. You're more actively involved in what is happening."

Volhein and Miller are members of the project's advisory board, which also includes representatives from various organizations. Several potential projects being considered by the advisory board are:

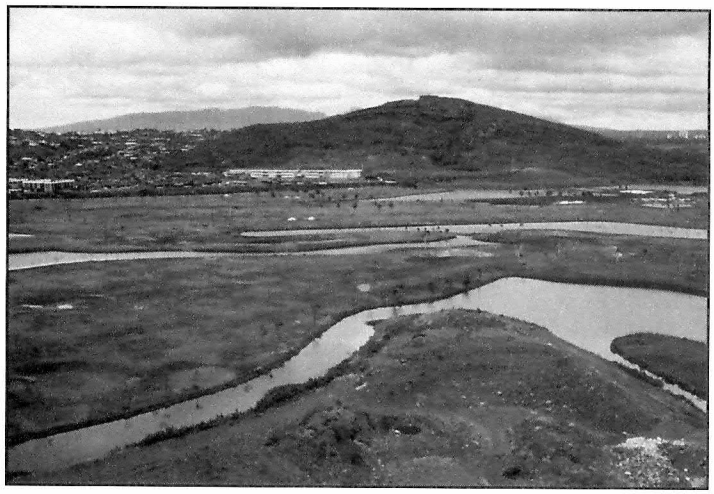
- characterizing streams and shorelines by photographing and surveying the type of stream bed and adjacent land, and recording the types of fish and aquatic insects found in the water
- picking-up and cataloging litter along the shore and streams according to type and amount to determine their origins
- making visual and photographic records of the

beach at frequent intervals to characterize the processes of accretion and erosion

- developing a resource collection at the community libraries for reports and maps on the local watershed
- analyzing the composition of sand to better understand the impact of plastics on coastal ecosystems
- collecting and analyzing water samples on a regular basis, including a period of rainfall, to better understand potential sources of sedimentation and other nonpoint source pollution.

The Hawaiian duck, or koloa, and her ducklings are one of the four species of endangered waterbirds that are endemic to Hawaii and live at Kawai Nui Marsh. –USFWS

The program will also provide information that could be used in implementing a management plan for Kawai Nui Marsh, which receives runoff from an 11-square mile watershed. The marsh is in a conservation district that consists of 750 acres of wetland, making Kawai Nui the state's largest freshwater wetland. In addition to hosting a swarm of insects and numerous aquatic animals, Kawai Nui Marsh is home to four endemic and endangered waterbirds — the Hawaiian stilt, Hawaiian gallinule, Hawaiian coot, and Hawaiian duck.



With the growth of urban development near the Kawai Nui Marsh, state leaders and environmentalists are counting on the water quality monitoring project to help ensure a healthy future for the marsh and Kailua Bay area. –USFWS

Historians are also interested in preserving the marsh because its vegetation holds valuable information on the ancient Hawaiians' migration and way of life. Planners are also learning that wetlands are most useful in their natural state, than when they are filled in or drained. Preserved wetlands can serve as nursery grounds for marine organisms, locations for agricultural crops, living sewage treatment plants, flood control basins, wildlife habitats, sediment filters, and buffers protecting coastal communities against erosion and storm damage, according to Dr. Diane C. Drigot, author of the book *Ho'ona'auao no Kawai Nui*.

Volhein said her students are interested in preserving the windward environment, including Kawai Nui Marsh, by taking part in the volunteer program.

"Most of them want to be involved," Volhein said. "They just don't know where to go and how to do it. They realize that there is a problem. The mind-set is changing. The youth are becoming more actively involved in taking care of the land and teaching people about it.

"The government can't do all of this by themselves. The more involved you are and the less you rely on government, the better the place you have . . . This is a beautiful place. We want to keep it that way."

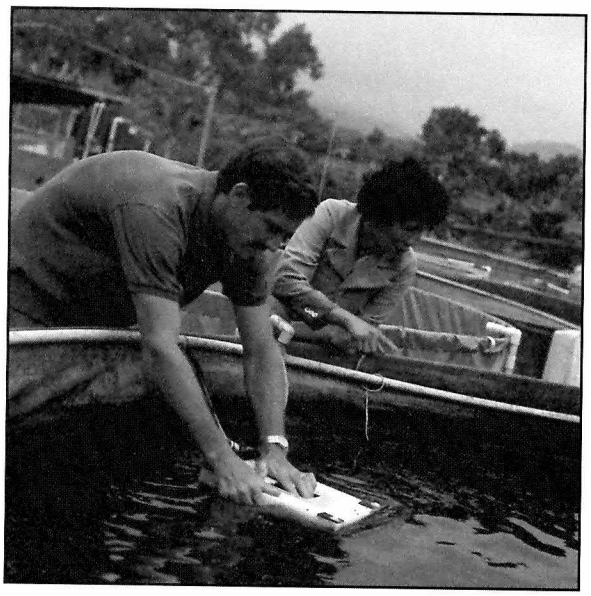
The volunteer water quality monitoring project's advisory group is made up of representatives from the following organizations:

- Waimanalo Neighborhood Board
- Kailua Neighborhood Board
- Save Our Bays & Beaches
- Ohana Council
- Kawai Nui Heritage Foundation
- Surfrider Foundation
- St. Louis High School
- Save Our Surf
- Windward Community College Marine Option Program
- State Department of Health
- City & County of Honolulu Public Works Department
- City & County of Honolulu Waste Water Management Department
- Sierra Club
- Save Mount Olomana Association
- Kalaheo High School

Self-Reliance in Backyard Aquaculture

When Quyen (pronounced queen) Le fled Vietnam and came to Hawaii, she had no money, no home, no friends, and she spoke no English. What she did have was four daughters all under the age of six. And, she had impeccable foresight.

Le and her husband started growing vegetables to survive and eventually began selling their crops for cash. Later, Le opened a travel agency and a jewelry store in Honolulu's Chinatown. But then came the recession and very few people were traveling or buying jewelry.



Paul Olin helps Quyen Le test water conditions in her backyard aquaculture tank. –J.L. Katter

Fortunately, a picture of "baby fish" in a magazine attracted Le's attention.

"I like and keep it," Le said. "I don't know why, I just keep. It looked interesting."

The picture was of "baby fish being taken out from a fish" and Le recognized the fish as *ca tre*, catfish, a delicacy in many Asian cultures.

Le held on to the picture for about three years, then decided she wanted to raise and sell the fish in the picture. She suspected that a demand for it existed in Hawaii because of the state's large ethnic population.

"I didn't know anything about fish farms," Le remembers. "I talk to many people, but they didn't look like they have a good idea, so I not interested anymore. Then I try again. I bought the frozen kind and bring to the University (of Hawaii), but they don't know too much.

"Then I try again. I call the University. I remember I hear a very friendly voice. I ask if he know how to make baby fish. I was so happy to hear his voice. He said, "Come tomorrow."

The voice belonged to Sea Grant Extension Aquaculture Specialist Paul Olin. The next day, Olin saw Le's picture of a fish being induced to spawn and recognized the fat, whiskered fish immediately.

"He laughed," Le said. "Then we went to Chinatown and we looked at all the different kinds of fish. He was very nice. He told me where to get baby fish. I call and I buy."

Today, Le and her husband own and operate Emerald Garden Farm, where they grow catfish and use the effluent to irrigate their herbs and vegetables. The species grown by the Les is called *Clarias fuscus*.

Nestled in the quiet foothills of the Koolau mountains on the north side of Oahu, the Le's farm resembles a piece of Vietnamese countryside. Exotic herbs, fruits, and vegetables, which Le says are similar to American species "but have no American name" grow in neat rows next to their home.

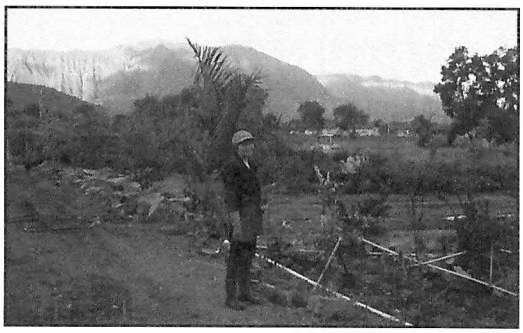
Three years ago, Le started off with six fish tanks. With the help of Olin and Sea Grant Extension Agent Rich Bailey, Le now has 17 tanks and 15,000 catfish.

"I want to keep going," Le said. "This year is the best year. At first, I lose money. The next year, I lose money. But I still happy. Every year I learn more, so soon I will have enough for my income."

Although giving people hands-on training is difficult, Bailey and Olin both find their work rewarding.

"You don't just talk about fish with them," Olin said. "You end up getting to know them and their family, and becoming friends with them. You really want them to succeed."

"We told her about mechanical feeders so that she could go to work at her other



Effluent from Quyen Le's aquaculture tanks is used to irrigate her farm. –S. Magaoay

job," Bailey said. "Feeders are not new, but she knew nothing about them."

Bailey said the two types of feeders, demand and belt, on Le's catfish fry nursery not only allowed her to work at the Chinatown store during the day, but also increased the growth rate and health of her "baby fish," or fry. With the demand feeder, fish touch a metal rod when they are hungry and food is released. The farmer only has to fill the feeders once every two days, decreasing the labor time of feeding.

"We get information from all over the world," Bailey explained. "We like to take science that has good potential for application and encourage people to use it."

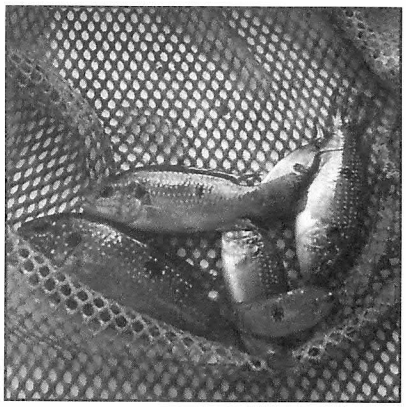
In addition to helping farmers who grow fish for ethnic palates, Sea Grant Extension has also been following the state's lead in looking for new markets in aquaculture through the Aquaculture Development Program. Twenty years ago, state leaders focused mostly on vast shrimp and prawn farms. Today, state leaders are encouraging aquaculture entrepreneurs to find a niche market. As a result, dozens of backyard aquaculture farms have sprung up in both suburban and country neighborhoods, raising everything from tilapia to angelfish and swordtails.

Although research takes years to complete, the information gained is priceless, especially for people like Quyen Le.

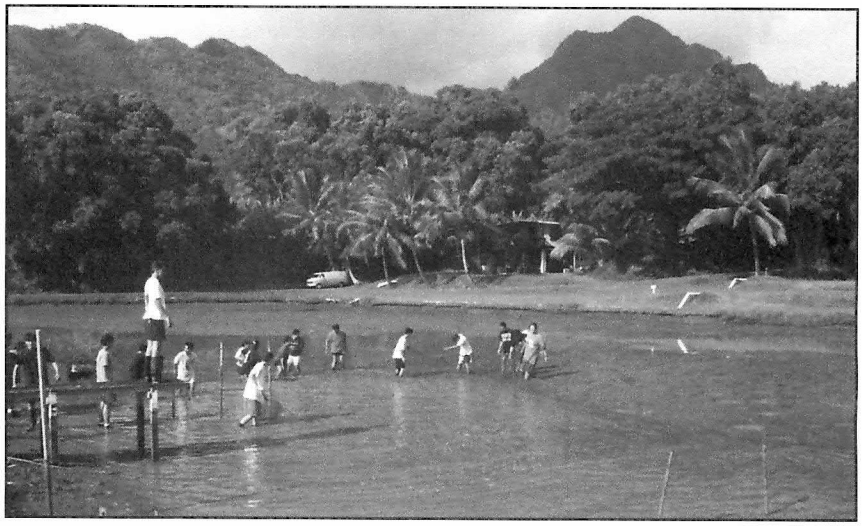
"I had to run away from Vietnam because of the war," Le said. "I come here. I had no money, no penny, no nothing. My children had to work."

Le's two oldest daughters are now in college and two are in high school. Le hopes to sell her jewelry business as soon as she works out the kinks in her catfish farm and expands it further. She is confident that her aquaculture venture will be a success.

"Now, I'm so happy I'm in the fish business," Le said. "People don't always need jewelry, but they always need to eat. I like the farm better. You have to work harder, but not too much stress. Jewelry business can go down. But the farm business always going. I'm so glad I met Paul and Rich, or I wouldn't be in this business."



Jewel cichlids, *a species of ornamental fish that was raised as part of a demonstration project, recently received clearing from the state's Aquaculture Development Program and will be distributed to local farmers. –R. Bailey*



Sea Grant Extension agents teach high school students how to use a seine net to harvest tucunare bass at the Mariculture Research and Training Center. –R. Bailey

Filling Niches in the Seafood Market

The Sea Grant Extension Service is working with the state and the United States Department of Agriculture Center for Tropical and Subtropical Aquaculture to develop a viable ornamental aquaculture export industry in Hawaii. State leaders hope to grab a piece of the $80 million market in ornamental fish annually and put a damper on the U.S.'s yearly import of Asia's 125 million fish.

"Hawaii really is the ideal place to grow ornamentals because of the state's year-round tropical climate. Not even Florida has that kind of weather," Paul Olin, Sea Grant Extension Aquaculture Specialist said. "Also, would you like to buy a fish that spent over 30 hours in shipping bags because it had to come from the Far East, or would you like a fish that spent about six hours in shipping bags?"

Researchers use these cages to determine the optimum density for swordtails in a demonstration project sponsored by the Center for Tropical and Subtropical Aquaculture, Sea Grant Extension, and the state's Aquaculture Development Program. –R. Bailey

Other niches that Sea Grant Extension experts are trying to fill are the marine shrimp and abalone markets.

Aquaculture researchers involved in Sea Grant's Marine Resources Development Program are also carrying out a wide-range of projects.

• Dr. E. Gordon Grau, a marine biologist, is hoping to combat the United States' $4.1 billion trade deficit in seafood commodities by developing a special feed that will improve the tilapia's growth and reduce costs to both the farmer and feed manufacturer.

His study targets the tilapia because of its hardiness, ability to grow fast, and popularity in supermarkets and restaurants. Grau's study is one of the few programs worldwide that addresses hormonal growth promoters for fish that live in warm waters.

• Grau is also developing a demonstration project for the sailfin molly. He is outlining the optimum pond, feeding, and hormonal treatment conditions for this ornamental fish.

Grau hopes to develop a pond production system that will permit farmers to maintain and grow mollies in fertilized ponds, thus reducing or eliminating the need for prepared feeds and resulting in higher profits. The demonstration project will also explore the suitability of molly culture in Hawaii and transfer the results to local farmers through Sea Grant Extension Service.

• What happens when a virus strikes a shrimp farm? Ninety percent of the juveniles may die. The only option for the farmer is to destroy the infected shrimp and start over. In Hawaii, eight viruses have been reported by the cultivated shrimp industry and at least two are being studied.

Virologist Dr. Philip C. S. Loh is working to develop a quick method to detect diseases in shrimp whose symptoms are not yet apparent. By identifying infected animals long before they show clinical signs, aquaculturists will be able to eradicate the viral problem more quickly and efficiently.

• Dr. Christopher Brown, an associate specialist at the Hawaii Institute of Marine Biology, is addressing the most expensive and labor-intensive aspect of fish culture — producing larvae.

Brown hopes to produce fish larvae of native Hawaiian species. Most Hawaiian species that are popular at supermarkets and pet stores have small larvae, making them difficult to raise in captivity. Brown's project will help aquaculturists meet the increasing demand for Hawaiian products.

Coconut Island is home to many Sea Grant researchers' laboratories. –Sea Grant file photo

Recent technical advances have also increased researchers' capability to induce spawning and facilitate the transfer of growth, development, and survival-promoting compounds to larval fishes. Brown is attempting to incorporate these compounds into the larvae by non-invasive procedures, thereby reducing stress on the small, delicate larvae. This is done by introducing the compounds to the larvae via the yolk, or by incorporating them into larval feeds.

From Scientists to the Public: Bridging the Gap

Guided by a vision for a new Sea Grant Extension frontier, a few local activities on ozone depletion have expanded into a coordinated, national global change education program with diverse outside funding in the span of five years. All of this was spearheaded by UH Sea Grant Extension's efforts.

As part of Sea Grant Extension education efforts, sunbathers, and anyone who steps outside of their home, are advised to cover up with sunscreen. –J.L. Katter

By the fall of 1988, scientists had collected alarming data to support the hypothesis that the earth was warming and the ozone layer was being depleted. However, to much of the general public, changes in the chemistry of the atmosphere seemed far removed from everyday life.

"In those early years of global change research, concern about global change was growing in the scientific community, but it wasn't translating into public awareness or action," said UH Sea Grant Extension Service global change project assistant Scott Bogle. "Some information was reaching the mass media, but its presentation was usually either too sensational or too technical."

Consider the following: A rise in sea level due to climatic change could affect coastal development and wetland ecosystems. A thinning ozone layer would mean increases in ultraviolet radiation, which might adversely affect the entire marine food chain, and ultimately, fisheries. All of this translates into potential harm to economies and ecosystems.

In light of these possibilities, Sea Grant Extension directors from the Pacific region decided it was time for Sea Grant to take concerted action. The general public needed to be educated on the potential impacts of global change.

"If the public was to respond to global change, awareness needed to be raised," said UH Sea Grant Extension Service Director Dr. Bruce Miller.

At Sea Grant Week 1989 in Charleston, South Carolina, Miller and Mike Spranger, director of Washington Sea Grant's Marine Advisory Service, worked to put global change education on Sea Grant's national agenda. Their call for the development of a coordinated, national education initiative led to the formation of an ad hoc committee of Sea Grant Extension directors to initiate local and regional education programs addressing global change issues.

"The ultimate goal of the initiative was to build understanding of these issues and encourage constructive responses," Miller said.

Left to right: Mike Spranger of Washington Sea Grant, Lynn Mortensen of Project Earthlink, Bruce Miller of Hawaii Sea Grant, and Lynne Carter of the University of Rhode Island. –S. Bogle

Early Sea Grant global change projects in Hawaii included workshops on climate and global change, coordinated activities for Hawaii Earth Day 1990, presentations for schools and community groups, and working with the state legislature on ozone protection legislation. Similar projects were implemented across the country by other Sea Grant programs.

"The shared objective was to bring these various local and regional initiatives together into a coordinated national program, and in so doing, make global change education a priority for Sea Grant nationally," Miller said.

That goal is now being realized. In the spring of 1993, the National Oceanic and Atmospheric Administration's (NOAA) Office of Global Programs provided funds for informal educator training workshops and program development in five Sea Grant regions. This regional focus allowed the workshops to tackle issues specific to each region, while at the same time creating a national network of educators. The creation of a sixth mid-continent region added a new dimension to Sea Grant education efforts by helping inland residents understand their links to the coast and ocean.

The first Pacific regional workshop was hosted by UH Sea Grant in November 1993 and attracted informal educators from museums, parks, aquariums, and nature centers.

"The workshop was eye-opening and provocative," said Marsha Erickson of the Kokee

Participants of the first Pacific regional workshop for informal educators, which was hosted by UH Sea Grant last year. –S. Bogle

Natural History Museum. Erickson said the museum, which is visited by over 100,000 people annually, will devote a portion of their exhibit space to global change.

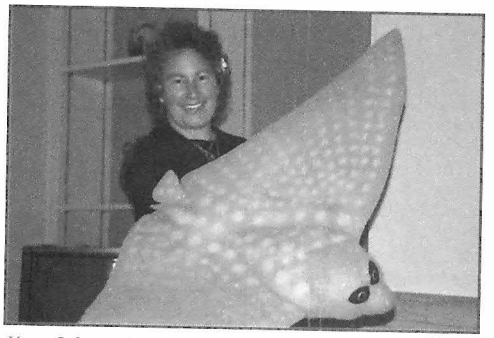
"The programs are designed to create a multiplier-effect," Miller said. In other words, educators who participate in the NOAA-sponsored workshops must commit to incorporating global change issues into their existing programs and organizing workshops for other educators in their home locations, which include Hawaii, the U.S. west coast, and several U.S.-affiliated Pacific islands.

Because of various Sea Grant Extension workshops, educators across the state have begun brainstorming ways they can pass on the knowledge to their various audiences. Purpleheart Puppets, a traveling group that uses large puppets and live music to build environmental awareness, is beginning to address global change messages in its performances. One elementary class will begin an air quality study on the Big Island. Environmental groups are making plans to set up displays with global change themes at shopping malls.

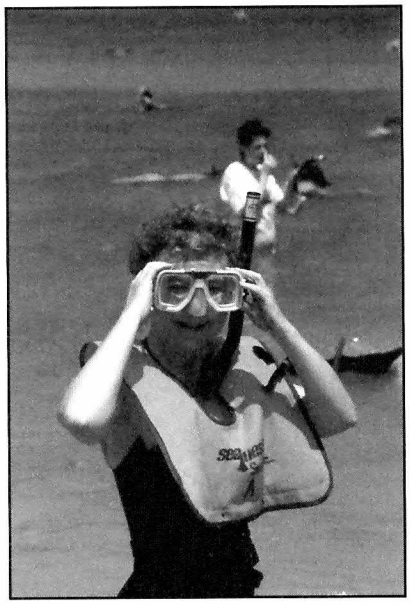
The regional workshops also utilize modern technological advances. Pending funding from NOAA, each Sea Grant region will hold simultaneous training workshops from 1994 to 1996. The workshops will be linked together via satellite. The result will be an exchange of information between hundreds of policymakers, researchers, experts, and educators from around the country.

The satellite-linked workshops in 1994 will be used to lay the foundation for Project Earthlink, an education initiative being developed by the federal interagency Subcommittee on Global Change Research.

"The 25th anniversary of Earth Day in 1995 will serve as the springboard for a long-term education program on global change," said Dr. Lynn Mortensen, manager of Project Earthlink. "In partnership with Earth Day USA, Project Earthlink plans include an interactive videoconference with community leaders across North America, construction of a 42-foot scale model of the



Kate Schuerch, of Purpleheart Puppets, holds a large spotted eagle-ray puppet. She is using these puppets to teach people about global change and other environmental issues. –S. Bogle



Global change affects everyone, including vacationing snorkelers. –S. Magaoay

earth by students, and a native American pow-wow."

The National Science Foundation has also gotten involved. In 1993, it provided funds for the travel expenses of seven teachers from Hawaii to participate in a three-week workshop hosted by Oregon Sea Grant. In turn, these teachers are helping to develop a workshop for 30 Hawaii teachers in the summer of 1994. As a result, hundreds of school children will have an understanding of ozone depletion, carbon dioxide, and global warming.

"All of these local educational outreach efforts are raising awareness among audiences that we would not be able to reach by ourselves," Miller said. "It's exciting because these networks will continue to grow in the coming years as educators are trained at Sea Grant workshops and then pass the information on to their colleagues. Through this network, students and the general public will receive the information they need to make informed, responsible choices regarding personal actions and public policies."