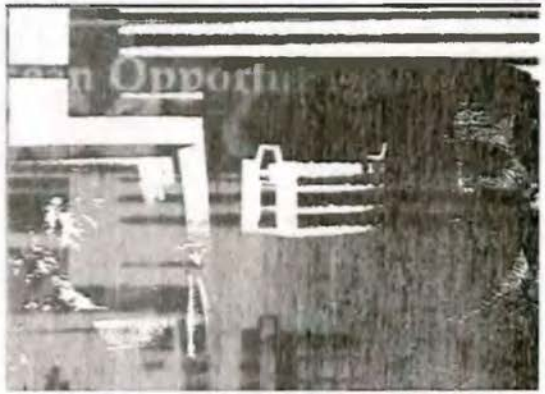
# Marine Science Caree

## A Sea Grant Guide to Ocean Opportunities

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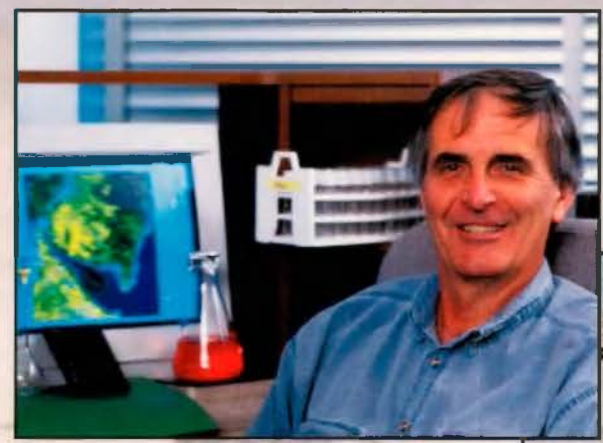

## Visit us online at:

# www.marinecareers.net

*Marine Science Careers* is a publication of the National Sea Grant College Program and a companion piece to the Sea Grant web site devoted to providing information on career opportunities in the marine sciences: **www.marinecareers.net**. The web site includes all of the information in this publication as well as additional profiles, information on salary levels for marine scientists, links to other sources of information on careers in the marine sciences, and a range of other features.

**Additional copies** of this publication are available from many of the Sea Grant programs listed on page 33 or for $5 a copy from either the Sea Grant Communications Office at the University of New Hampshire (Sea Grant Communications, Kingman Farm/UNH. Durham, NH 03824-3512 — checks payable to UNH) or the one at the Woods Hole Oceanographic Institution (WHOI Sea Grant Communications, 193 Oyster Pond Road, CRL 209, Woods Hole, MA 02543-1525 — checks payable to WHOI).

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# Marine Science Careers

# Welcome to Marine Science Careers

**Students thinking about careers** in the marine sciences often picture themselves working with marine mammals. Within the marine science fields, however, only a few scientists specialize in that area. This second edition of *Marine Science Careers* will introduce you to a wide range of marine career fields and to people working in those fields. In addition, it will give those men and women a chance to tell you what they like and dislike about their careers, what they see for the future in their fields, and much more. This publication will also provide you with some experts' views on what the future holds for marine science careers.

Before we get to that, though, we'd like to introduce Sea Grant, the publication's sponsor. A component of the National Oceanic and Atmospheric Administration (NOAA), the National Sea Grant College Program is a federal-state partnership. It supports marine-related research, education, and extension activities. These activities help us learn more about our marine resources and improve how we use them. Sea Grant operates through a network of academic and research institutions located in our ocean and Great Lakes states as well as in Puerto Rico. The state and regional Sea Grant programs (listed inside the back cover) are good sources of marine-related information. Don't hesitate to contact them.

- What is your current job and what does it entail?
- What was the key factor in your career decision?
- What do you like most about your career?
- What do you like least about your career?
- What do you do to relax?
- Who are your heroes/heroines?
- What advice would you give a high school student who expressed an interest in pursuing a career in your field?
- Are career opportunities in your field increasing or decreasing and why?
- What will you be doing 10 years from today?

As noted earlier, Sea Grant operates in the Great Lakes states as well as in the ocean states. This publication reflects that by including profiles of several people whose careers involve those lakes rather than the oceans. Because the Great Lakes and the oceans have many similarities, scientists studying them face similar challenges.

The people featured in *Marine Science Careers* cover a wide range in many ways. Some work at colleges and universities; others work for the local, state, or federal government. Others are with marine-related industries, research laboratories, independent organizations, or consulting firms. They come from around the country and represent a variety of educational backgrounds. Some are in the early stages of their careers while others are well established in theirs.

We asked each a set of questions designed to meet the information needs of students with an interest in marine careers. We present their answers here, allowing them to profile themselves.

Before you go off to explore the publication, we have a few words of advice to offer. First, be flexible. It's fine to opt for a marine science career at an early age, but it's a mistake to decide your exact specialty before you've had a chance to explore your options. Second, take advantage of the opportunities that exist to get hands-on experience through marine education programs. Third, take as many math, science, and computer courses as you can in school. Also, pursue related studies as part of independent studies projects. Fourth, don't expect preparing for a marine science career to be easy. Fifth, don't give up. Good luck.

**Steve Adams**
NH Sea Grant

**Tracey Crago**
**Sheri DeRosa**
WHOI Sea Grant

# Marine Biology

**The field of marine biology** — the study of marine organisms, their behaviors, and their interactions with the environment — is considered one of the most all-encompassing fields of oceanography. To understand marine organisms and their behaviors completely, marine biologists must have a basic understanding of other aspects or "disciplines" of oceanography, such as chemical oceanography, physical oceanography, and geological oceanography. Therefore, marine biologists and biological oceanographers study these other fields throughout their careers, enabling them to take a "big picture" approach to doing research.

Because there are so many topics one could study within the field of marine biology, many researchers select a particular interest and specialize in it. Specializations can be based on a particular species, organism, behavior, technique, or ecosystem. For example, marine biologists may choose to study a single species of clams, or all clams that are native to a climate or region.

One area of specialization, the emerging field of marine biotechnology, offers great opportunity for marine biologists. Marine biotechnology research presents a wide range of possibilities and applications. One focus area is the biomedical field, where scientists develop and test drugs, many of which come from marine organisms. An example of an application of biotechnology research can be seen in industry or defense, where researchers have developed non-toxic coatings that prevent the build-up of fouling organisms, such as barnacles and zebra mussels. Such coatings are useful for ships and intake pipes used in power plants.

Molecular biology is a related area of specialization in this field. Researchers apply molecular approaches and techniques to many environments, from coastal ponds to the deep sea, and many different organisms, from microscopic bacteria, plants, and animals to marine mammals. For example, molecular biology can be used to identify the presence of a specific organism in a water sample through the use of molecular

*(continued on page 5)*

## Shannon Atkinson — marine biologist


**B.S. and M.S., animal science, Univ. of Hawaii**
**Ph.D., veterinary sciences, Murdoch Univ.**

**current job:** I am an associate researcher at the Institute of Marine Biology of the University of Hawaii. I conduct research on a variety of species from corals to seals and whales. The research focuses on reproductive and growth biology. I also advise graduate students.

**key factor:** I enjoy research and I love working with animals. I debated about becoming a veterinarian or doing research; research keeps my mind active and it always poses new challenges and interesting topics.

**like most:** I love working with animals and understanding how and why nature works the way it does. I feel in touch with the world around me and enjoy watching animals in a natural setting and trying to figure out why they do what they do.

**like least:** I dislike the increasing volumes of paperwork, especially for endangered species research.

**relax:** I enjoy my family, hiking, swimming, and being in remote places. All of these activities provide relaxation and time to contemplate the meaning of life.

**heroes/heroines:** My mother is my biggest heroine. She is smart and calm, and has always been supportive.

**advice:** Study hard, stay in science, and be persistent.

**career opportunities:** I see increasing need to understand the biology of individual species and ecosystems. With the human population increasing, we are putting increased pressures on ecosystems and the organisms within them.

**10 years:** Probably the same thing, but life holds surprises and one should never take it for granted.

## Kevin McAllister — baykeeper

**A.A.S., natural resources conservation, State Univ. of New York at Morrisville**
**B.A., biological sciences, Florida Atlantic Univ.**
**M.S., coastal zone management, Nova Southeastern Univ.**

**current job:** I am the Peconic Baykeeper on the east end of Long Island, N.Y. The Peconic Baykeeper Program is part of a fast-growing grassroots environmental movement, the Water Keeper Alliance. I regularly patrol the bays to monitor shoreline activities

## You Say "Marine Biology," I Say "Biological Oceanography"

Throughout this publication, you will come across the terms "marine biology" and "biological oceanography," often used interchangeably.

One distinction that has been made between the fields of marine biology and biological oceanography is this: marine biologists study the plants, animals, and protists of our estuaries, coasts, and oceans, ranging from whales to microscopic algae and bacteria, and biological oceanographers study marine organisms and their biological processes within the context of their natural environment. In that sense, marine biology could be considered a subset of biological oceanography.

Another way of looking at it, says Larry Harris, a professor of zoology at the University of New Hampshire, is "marine biology is biology with salt added. You can do many kinds of biology and be a marine biologist as long as you are working with marine organisms or marine systems." While it is true that some marine biologists have little or no training in oceanography, especially at the undergraduate level, others have a great deal of oceanography background.

In any case, don't let the terminology get you confused! Instead, read the profiles featured here to meet people working in a career area, specialty, or field that interests you, and use their experiences and background as a guide. Remember, there are many paths available to you and many choices you can make to get to where you want to be.

and to identify pollution problems. In doing this, I work closely with the community (residents, businesses, and government) to find solutions to environmental problems in the estuary.

**key factor:** I was introduced to the marine environment at an early age. Growing up close to the bay, I had the opportunity to spend countless hours on it, in it, and along its shores. Through these experiences, I knew it was my calling to work in environmental protection.

**like most:** Smelling the roses. Spending time on the water patrolling the bays and experiencing the natural beauty of the estuary.

**like least:** The politics and hidden agendas that often compromise the integrity of the decision-making process involved in environmental protection issues.

**relax:** I enjoy all water sports: rowing, surfing, sailboarding, swimming, diving, etc. However, the greatest enjoyment I have is when I'm introducing my son to new adventures where I'm able to live vicariously through his eyes.

**heroes/heroines:** I really haven't any. Although, I will say that I admire and respect Robert F. Kennedy Jr. for all he has given of himself in the effort to protect our nation's waterways.

**what advice:** Get involved by volunteering with organizations to get some practical experience. When you're qualified for employment you'll have a leg up. Most importantly, most of us enter the field for reasons other then making the big bucks, so stay true to yourself and your passion for the work.

**career opportunities:** I believe the opportunities are increasing. Work hard towards getting the appropriate education and get involved.

**10 years:** I believe in 10 years the Water Keeper Alliance will be a powerful force throughout the nation, representing the public's inherent right to clean water, and I fully expect to be part of the team.

## Tracy Leigh Karmuza
### — marine mammal specialist

**B.A., psychology, Florida Institute of Technology**

**current job:** I am an animal care specialist with the Ocean Futures Society working to return a whale named Keiko (a.k.a. Free Willy) to the wild. I am responsible for the daily care of this killer whale in a field situation. I currently live in Iceland and work on a floating bay pen.

**key factor:** I have always been fascinated with the ocean and all types of sea life. I knew I wanted to work in the marine science field. I was lucky in that I met wonderful people who helped me attain my goal.

**like most:** Caring for live animals is always an exciting job. We are also conducting research studies on other marine mammals in the North Atlantic. The education aspect is very important to me, and I enjoy being able to answer the questions the public has about the lives of these magnificent animals.

**like least:** The politics of working with a live animal are always frustrating. You're always on call, because working with a marine mammal is not a 9-5 job.

**relax:** I enjoy all water sports, especially warm water scuba diving. I also enjoy reading, hiking, and traveling.

probes. This is very useful when the organism in question is microscopic or similar to other organisms. The study of disease in organisms has also been aided by the use of molecular techniques. Researchers have developed antibodies that are specific to a particular virus, so that when the virus is present in the organism, detection and diagnosis is easier and faster. Likewise, new molecular techniques help scientists identify whether or not an animal has been exposed to pollutants and, in some cases, can determine the source of those pollutants. The field of molecular biology is growing and will continue to see significant advances.

Aquaculture, the farming of finfish, shellfish, and seaweeds, is another field that has been aided by marine biotechnology and molecular techniques. Aquaculture is gaining importance in this country as consumer demand for fish and shellfish becomes greater than can be met by traditional commercial fishing. At the same time, technological advances have made aquaculture more economically feasible. In one example, researchers developed a "triploid" oyster, whose meat remains firm and sweet throughout the entire spawning season (May to August). By extending the harvesting and marketing season of the oyster, its economic value increased.

Marine researchers are also experimenting with ways to administer drugs to diseased populations of farm-raised fish. Disease can wipe out an entire crop of farm-raised fish or shellfish due to the confined setting in which they are raised. One technique involves exposing a pen of fish to ultrasound (high frequency sound that cannot be heard by humans). This causes the outer layers of the fish tissues (skin and gills) to become more permeable, making the fish more receptive to a vaccine or antibiotic drug that is released into the water.

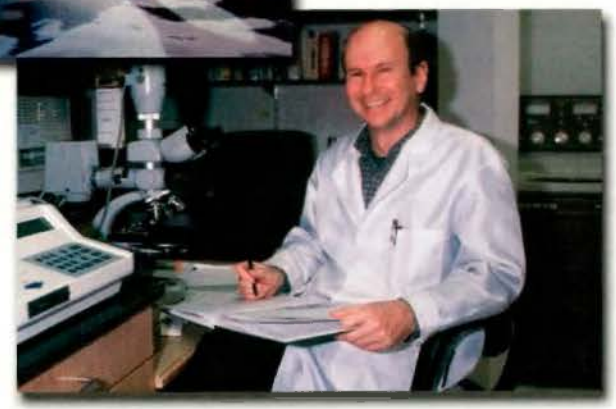
Other popular areas within the field of marine biology are environmental biology and toxicology. Both of these areas have direct applications and implications for our society. Examples of specialities in environmental biology and toxicology include water quality research and the study

**heroes/heroines:** My mother, who taught me to never give up on my dreams. All educators, who give their time to teach the public and try to make a difference in the world.

**advice:** Intern or volunteer and get as much experience as possible. Be persistent, work hard, and never give up.

**career opportunities:** I believe that they are increasing due to the expansion of marine facilities and the heightened awareness of our effect on the marine environment.

**10 years:** I will be working in the marine science field, caring for animals and educating the public on marine life and the oceans' importance.



## Russell Hill
### — marine biotechnologist

**B.S., biological sciences/microbiology and plant physiology, Univ. of Natal, Durban, South Africa**
**Ph.D., microbiology, Univ. of Cape Town, South Africa**

**current job:** i am an associate professor at the Center of Marine Biotechnology, University of Maryland Biotechnology Institute. My research is on various aspects of marine microbiology, especially the study of marine bacteria that may be important sources of new bioactive compounds, such as antibiotics.

**key factor:** The first important step was deciding to study microbiology. My move into the marine environment came later in my career, after I had finished my Ph.D. I joined the laboratory of Dr. Rita Colwell because of her interest in marine microbial ecology. I loved the marine work and am now lucky enough to combine two great interests, microbiology and the marine environment.

**like most:** I enjoy spending time at sea and have had the opportunity to dive in two research submarines, the ***RSV Alvin*** and the ***Johnson Sea-Link***. I like actually working in the laboratory, playing with my bacteria. I appreciate the freedom that I have as a researcher to set my own goals and follow my own research interests. It is also great to have many opportunities to travel and to work with people from different countries.

**like least:** Writing grants and working on budgets.

**relax:** I work out at the gym and enjoy doing practical things such as gardening and maintaining my own car. I enjoy photography and visit photographic exhibitions. I used to do a lot of sailing, but don't find the time for it now. I want to start sailing again because it is the ultimate relaxation for me.

**heroes/heroines:** Nelson Mandela, for having the courage of his convictions and for his role as a statesman in South Africa and the world. The men and

of contaminants or pollutants in the coastal or marine environment. Laws, regulations, and cleanup measures designed to protect the environment will ensure that marine and environmental biologists and consultants continue to play an important role in our society.

Another field of research within marine or aquatic biology involves organisms that have been around for billions of years: protists. Protists are singled-celled organisms that include protozoa and microalgae. They range in size from about two micrometers (.00008 inches) to just under an inch. Their importance as a group lies in the fact that microscopic algae serve as food for animals in aquatic food webs, earning them the title "primary producers." And since primary producers are mostly microscopic species, the organisms that consume them are often single-celled, microscopic species as well. If something happens to somehow alter populations of primary producers, the entire food web could be affected.

Probably the topic most often asked about within marine biology is research involving marine mammals, including cetaceans (whales and dolphins) and pinnipeds (sea lions, seals, and walruses). The reality is that research jobs involving marine mammals are extremely hard to come by for a number of reasons, including the popularity of the field, the fact that working with marine mammals is highly regulated (most research is done using tissue samples of sick, stranded, or dead animals and not on live, healthy animals), and because funding is very competitive.

Two popular fields of research involving marine mammals are bioacoustics and vocalization (the study of marine mammal sounds), and population dynamics (studying marine mammalian behaviors and responses to environmental conditions as they impact population). As for non-research employment options involving marine mammals, most positions would exist at aquaria, museums, and national and international conservation groups, though these are also highly competitive. ●

women who serve as crew on research vessels, persevere under difficult conditions, tolerate sometimes difficult and eccentric scientists, and keep marine science moving forward.

**advice:** Develop a strong academic background. Make sure that you study molecular biology if you want to work as a marine biologist because molecular techniques are becoming increasingly important in all aspects of biology. Work in many different areas of biology while you are at high school and college. Many researchers will take on volunteers over the summer and this is a great way to get experience and find out which aspects of marine biology are the most enjoyable for you.

**career opportunities:** Increasing. There is a growing awareness of the importance of microbiology in all marine processes. Marine biotechnology as a field is also growing in importance. There are many practical applications of marine biology and biotechnology in drug discovery, aquaculture, and monitoring for pathogens in the marine environment.

**10 years:** I hope to still be running my own laboratory, as a tenured professor. I will be supervising a fairly small but active group of graduate students and post-docs. We will be making a major contribution to the isolation of novel microbes that produce important pharmaceuticals and industrially important enzymes.

## Janice Sessing
### — marine biologist

**B.S., marine science and biology. Univ. of Miami**
**M.S., animal sciences, Univ. of Hawaii at Manoa**

**current job:** I work for the National Oceanic and Atmospheric Administration (NOAA). I am an international relations specialist with the National Environmental Satellite, Data, Information Service (NESDIS). I apply my scientific training as a marine biologist to support NESDIS' goals of acquiring and processing satellite data and disseminating derived products to support a number of oceanic, terrestrial, and atmospheric applications by domestic and global customers.

**key factor:** The opportunity to get paid to go to the beach. Seriously, I wanted to make a difference in an emerging field and the marine sciences provided an opportunity to do that.

**like most:** Being involved in projects and programs that involve ocean, coastal, terrestrial, and atmospheric issues at local, national, and international levels. I work for an agency that has allowed me the opportunity to work in different positions. Some of my experiences include working in Hawaii to develop a national marine sanctuary to protect the humpback whale and its habitat, representing NOAA on government delegations to a number of United Nations and other international meetings, and working with a task force to develop a federal framework for aquatic nuisance species in the marine environment. My current position allows me to work with remote sensing specialists involved in making technology that seemed too "high-tech" a few years ago useful for ocean and coastal management.

**like least:** The oftentimes slow process of change within a government bureaucracy.

**relax:** Travel (domestic and foreign), pottery, theater, reading, volunteer work.

**heroes/heroines:** People who are at the forefront of making a positive change at all costs, and who have demonstrated personal and professional integrity and commitment to their cause.

**advice:** Every experience, good and bad, is a good teacher. Get a solid foundation in the sciences, especially calculus, physics, and biochemistry. Find a mentor and apply yourself to achieve your goals. Pursue internships, fellowships, and other opportunities, even if they are outside your field of interest. You will learn something from each one.

**career opportunities:** There are increasing opportunities for scientists, especially those in interdisciplinary areas such as the marine sciences. The opportunities exist to implement the recent global environmental agreements and programs within a number of United Nations specialized agencies, such as the Environment Programme, International Oceanographic Commission, and World Meteorological Organization.

**10 years:** I do not know, but am open to whatever presents itself.

## Stephen Truchon
### — marine ecologist

**B.A., biology, Plymouth State College**
**M.S., zoology, Univ. of New Hampshire**

**current job:** I am a marine ecologist with Exponent, a consulting and engineering firm in Boston. Most of my work involves evaluating habitats and aquatic biota in contaminated marine and estuarine ecosystems. Generally, I spend 75 percent of my time in the office and 25 percent in the field. The office work includes writing proposals, managing projects, analyzing data, and writing reports. The fieldwork includes evaluating habitat quality and resource value, and sampling surface waters, sediments, and biota of both contaminated and uncontaminated sites.

**key factor:** I have always loved the ocean. When I was 17, I took a scuba diving course that exposed me to the ocean and the interesting life in it. I wanted to know more about what I was seeing, so when I entered college I took as many marine biology courses as possible.

**like most:** I enjoy the challenge of designing and conducting a focused environmental sampling program, analyzing the data using statistical methods, and writing the results and conclusions. Essentially, it's my involvement in a project from start to finish that I enjoy the most.

**like least:** Most of the time the work is very stressful, with tight deadlines and slim budgets. As a result of these constraints, it is sometimes harder to enjoy the fact that I am actually getting paid to collect sediment cores in the marshes of Maine, conduct fish community surveys on a coral reef in Puerto Rico, or lead a habitat assessment in the tidal creeks of Georgia.

**relax:** I like to play with my children (Sarah and Nicholas), go out to dinner with my wife (Elizabeth), run on the beach, scuba dive, golf, or read a good underwater espionage book by Clive Cussler. Recently, I read ***The Perfect Storm*** by Sebastian Junger — I highly recommend it!

**heroes/heroines:** Richard Truchon (my father), Richard Fralick (a Plymouth State College professor), Libby Hyman (invertebrate zoologist), and those who give their time and effort to bettering the lives of children.

**advice:** Try to get some experience in the marine sciences by working as a library assistant, laboratory assistant, or teaching assistant. Ask your science teachers or guidance counselors if they can help you find such an opportunity at local colleges, government agencies, or private firms. You might be able to find a job sorting biological samples, prepping labs, conducting computer searches, entering data, or even assisting in fieldwork. Whatever you can do now will only help you when you apply to college.

**career opportunities:** In environmental consulting, opportunities for marine scientists are growing, particularly for those with an M.S. or Ph.D. Marine scientists with technical abilities in photoimagery analysis, biostatistics, sediment toxicology, and other such areas are frequently sought after and tend to assume more of a role in the decision-making process of research projects. Also, individuals who can serve in more than one capacity — as a manager, a technical specialist, and on a field crew, for instance — are more marketable than those who cannot.

**10 years:** I will probably be a principal scientist for an environmental consulting firm. As I get closer to retirement, I would like to shift the emphasis of my career towards teaching biology at the high school or college level.

## Deborah A. Bouchard
### — aquaculture microbiologist

**B.S., microbiology, Univ. of Maine**

**current job:** I am the president and co-owner of Micro Technologies Inc., an aquaculture diagnostic laboratory located in Richmond, Maine. The aquaculture diagnostic workload consists primarily of performing fish health inspection and certification procedures on cultured species for aquaculture companies located throughout New England and the Maritime Provinces. Fish health inspection work is performed in order to establish the health status of cultured aquatic species and to avoid the possible dissemination of disease to

natural resources. I am a certified fish health inspector for both the United States and Canada.

**key factor:** My experiences as a student in the microbiology department at the University of Maine.

**like most:** I work both in an outdoor environment and in the laboratory. I enjoy working at the aquaculture marine sites and hatchery locations. It is a pleasure interacting with the clients in a hands-on situation. I also enjoy performing the technical microbiology tests at the laboratory.

**like least:** At present, my position involves a somewhat unpredictable work schedule controlled by factors such as weather and fish life cycles. These factors can result in 15-hour work days with no rest the following days because of testing procedures.

**relax:** I enjoy dancing, photography, weight lifting, walking, and reading novels.

**heroes/heroines:** I really admire people who stand up for what they believe in and live by their convictions even in the face of obstacles.

**advice:** There are many courses of study you can choose from to pursue a career in marine sciences. Choose the one that interests you the most. Enjoy your college years. Leave all your options open and volunteer for every source of work experience possible.

**career opportunities:** Opportunities are increasing in the area of aquatic animal health. Aquaculture is a new and expanding field. As the type and number of cultured organisms increases, so will the demand for aquaculture support and health specialists.

**10 years:** It's difficult to determine what I will be doing in 10 years. My career has changed and progressed. I leave all options open. As a company owner I will focus on new business possibilities and growth. Micro Technologies Inc. started with two employees working out of one room and now, two years later, has five employees with a fully equipped lab. A little hard work goes a long way.

## Derrick R. Toba
### — shellfish biologist

**B.S. and M.S., fisheries, Univ. of Washington**

**current job:** I work as a shellfish biologist for the Tulalip Tribes of Washington. I work as a tribal representative on multi-jurisdictional committees and workgroups discussing all aspects of shellfisheries management and resource conservation. This includes working on management agreements with state agencies and other tribes, serving on regional committees and attending conferences on exotic species and shellfish sanitation, and reviewing and commenting on shoreline applications as they impact tribal resources.

My responsibilities include providing technical support and advice regarding shellfish matters, harvest management of the shellfish resource, shellfish enhancement projects, and water quality issues relating to shellfish bed degradation. I am also responsible for the implementation of tribal policy relating to shellfish. Part of my time is spent in the office and part in the field. Field studies include collecting biological information on crab and shrimp, as well as collecting water and shellfish samples to determine shellfish sanitation and to check for marine biotoxins.

Because of limited funds and efforts, the Tribes need to work closely with the state and local governments, non-profit organizations, and area residents to manage their resources properly.

**key factor:** There were two factors. The first was spending a lot of time near the ocean growing up in California and during summers spent with family in Hawaii. I was interested in the intertidal pools along the California shore and the reef systems in Hawaii. I was drawn more toward the invertebrates than the fish. The second factor was my major professor and mentor at the University of Washington, Dr. Ken Chew. His specialty in molluscan aquaculture was a positive influence in directing my career to shellfish. He continues to be my mentor and guide me along.

**like most:** I like the variety of species and projects that I work on. Different fisheries are managed in various ways, ranging from passive to active management. In addition, I have the opportunity to participate in aquaculture-related enhancement efforts. I also work on non-shellfish related projects, such as non-native aquatic weeds and water quality issues. I am fortunate in that I have the opportunity to work with my counterparts with the other agencies and tribes.

**like least:** Most of my time is spent in the office, at meetings, or on conference calls. I would prefer more field work. It is

*(continued on page 32)*

A narrative that attempts to cover three major disciplines of oceanography — marine geology and geophysics, physical oceanography, and marine chemistry and geochemistry — should be prefaced with the explanation that these sub-fields of oceanography are related. Oceanographers and others involved in these disciplines often work together to unravel the mysteries and unknowns of ocean science. In many government-sponsored research efforts, preference is given to projects that integrate the separate disciplines of oceanography and incorporate important principles from each to better understand a system, phenomenon, event, or process.

As a growing global population stresses the ability of our society to produce food, water, and shelter, we will continue to look to the oceans to help sustain our basic needs. Advances in technology, combined with demand, will improve our ability to derive food, drinking water, energy sources, waste disposal, and transportation from the ocean. It will be up to this and future generations to build upon our existing knowledge of the ocean and its potential to help meet the needs of the world and its inhabitants.

In reading about each of these sub-fields, keep in mind that some of the most important oceanographic discoveries have been made as a result of an integrated, multidisciplinary approach, often involving geologists, chemists, biologists, physical oceanographers, and engineers.

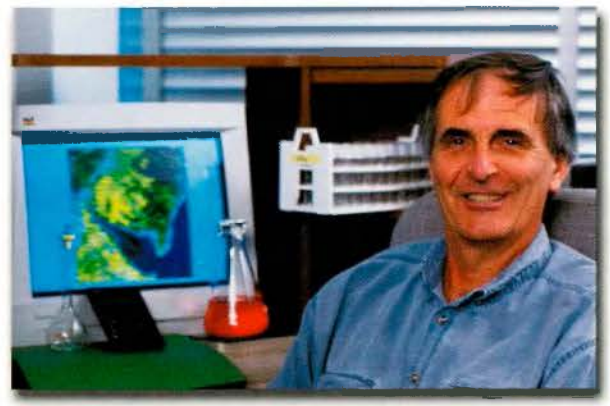
The 1977 discovery of active hydrothermal vent communities illustrates the benefits of this multidisciplinary approach. At these active hydrothermal vent sites, oceanographers observed thriving populations of hundreds of "new" species, including tube worms and giant clams. "Black smoker" chimneys also were observed, venting hot, metal-rich fluid that generates from within the Earth's crust and can reach temperatures as high as 350°C. Just outside these chimney-like structures, the water is much cooler — about 2°C — and has a higher pH. When these fluids meet, a reaction takes place and forms black "smoke."

Although the vent sites are located at the

# Oceanography

## Jonathan H. Sharp
### — chemical oceanographer

**B.A., biology, Lehigh Univ.**
**M.S., biochemistry, Lehigh Univ.**
**Ph.D., oceanography, Dalhousie Univ.**



**current job:** I am a professor of chemical oceanography at the University of Delaware. My responsibilities include research, teaching, and service. My research is primarily involved with biogeochemical studies of the beginnings of food chains in oceans and estuaries. Specifically, we try to better understand the interchange of carbon, nitrogen, phosphorus, oxygen, and silicon between the water and microscopic algae and bacteria. I teach general oceanography at the undergraduate level, but most of my teaching is with graduate classes in chemical oceanography and through advising M.S. and Ph.D. students. I am also involved with resource managers in development and implementation of coordinated monitoring and management plans for estuarine and coastal waters.

**key factor:** As a child, I was interested in nature and the environment. As I studied science in high school and college, my environmental interests grew with emphasis in the oceans. In contemplating graduate studies, I realized that my interests were multidisciplinary rather than being in a single science discipline. That ultimately led me into oceanography, a field where multidisciplinary research has been encouraged for many years.

**like most:** I like the thrill of working on research problems that are on the edge of "new frontiers" in scientific understanding. We know so little about the real "workings" of the marine environment that our research constantly sheds light on new concepts and on new paradigms. I also like the fact that application of our research can have real-time relevance to societal problems.

**like least:** Perhaps the most frustrating aspect of my career is that there are many fascinating research questions that I would like to investigate, but time is limited and it is difficult to obtain the funding to pursue many of the problems.

**relax:** I enjoy the out of doors and love skiing and sailing when I can find the time. I enjoy music, mainly classical, and live theater.

**heroes/heroines:** Thomas Jefferson and Benjamin Franklin. Both had amazing inquiring minds and were very creative thinkers and researchers.

**advice:** Study basic science and math and excel in whatever you do. Marine science is a composite of various applied sciences. However, in order to do well in the applied areas found in oceanography, one must have a solid science and math background.

bottom of the ocean floor where there is no light, life is plentiful. Scientists discovered that the chemistry of the water at these vent sites provides energy for bacteria to grow by chemosynthesis, in much the same way sunlight provides energy for plants to grow by photosynthesis.

### Marine Geology and Geophysics

As many interesting geological features as there are on land, nearly as many exist within, under, and at the boundaries of the oceans. Mountains, valleys, volcanoes, islands, plains, canyons — all exist in similar form in the marine realm. In fact, Earth's largest continuous mountain chain is the Mid-Ocean Ridge, stretching for over 40,000 miles and rising above the surface of the water in a few places, such as Iceland. The Mariana Trench, located in the central Pacific Ocean, is deeper, by about a mile, than the highest point of Mount Everest. Active deep-sea volcanoes, located along mid-ocean ridges, supply rich mineral deposits and new rock formations on the seafloor. Marine geologists locate the underwater volcanoes by using sonar and acoustic techniques that bounce sound waves off rock formations. They also use remote sensing technology to map the ridges and valleys. It has been written that the ocean bottoms are the most active places on Earth, from a geological perspective.

Conditions at many of these sites make it difficult for marine geologists to visit and study. Before the technological advances of only a few decades ago — piloted submersibles, remotely operated vehicles (ROVs), and programmable acoustic instruments attached to ships — oceanographers could only speculate about the very existence of underwater geological features. Such advances have not only proven the existence of underwater features, they have made it possible to develop accurate maps and detailed, 3-D computer models of the seafloor.

Geological oceanographers study the formations, composition, and history of the seafloor. They examine sediments, including physical characteristics such as size, shape, color, and

**career opportunities:** I feel that career opportunities in oceanography are increasing and potentially increasingly dramatically. We are currently facing and will face even more serious environmental problems in the 21st century. We need individuals with strong multidisciplinary training to attack these problems; research-oriented training in oceanography is an ideal background for such attacks.

**10 years:** I plan to be continuing my research and teaching with enthusiasm.

## Dawn Wright
### — geological oceanographer

**B.S., geology, Wheaton College**
**M.S., oceanography, Texas A&M Univ.**
**Ph.D., geography and marine geology, Univ. of California, Santa Barbara**

**current job:** I'm a professor at Oregon State University where I'm responsible for teaching four or five courses a year in my specialties: oceanography, geographic information systems (GIS), and general earth science. I also maintain a strong research program in seafloor mapping, seafloor tectonics, and GIS; advise undergraduate students; and help master's and Ph.D. students complete their theses and dissertations. In addition, I perform various kinds of professional and university service (serving on many committees, reviewing articles and proposals, etc.)

**key factor:** Growing up in Hawaii and watching ***Jacques Cousteau*** on Sunday nights! Seriously!

**like most:** Going to sea on big research ships and working with the equipment at sea. I've also met some extremely interesting and fascinating people from all over the world.

**like least:** Sometimes it takes forever (i.e., months to years) to get your ideas funded and then later published in a reputable journal. Both processes can be very laborious and difficult. But it is definitely worth it!

**relax:** I love cycling, watching cartoons with my dog, and going to movies with friends. I also never turn down an opportunity to ride a roller coaster.

**heroes/heroines:** I am a big fan of Sylvia Earle, not only because of her many scientific accomplishments but also because she is so captivating as a speaker and motivator to the general public. I also greatly admire my mother, as well as Winona LaDuke, Lani Guinier, Amy Grant, Miguel Indurain (five-time winner of the Tour de France), Billy Graham, and Julian Bond. My favorite historical figures are W.E.B. DuBois and Chief Joseph of the Nez Perce.

**advice:** Once you decide on what you would like to do, pursue it with great passion! This will tide you over during the difficult times. Find a hero or heroine to inspire you and follow their work/accomplishments. Don't shy away from math and computer programming! Get some hands-on experience at sea, such as a short internship or "semester at sea," if at all possible. And if you really want to lead a fulfilling life as an oceanographer, you should definitely think about going to graduate school.

**career opportunities:** Unfortunately, opportunities seem to be decreasing at the moment, particularly for oceanographers with Ph.D.s. The number of scientists has steadily increased over the last 10 years or so, with not as many of the older scientists retiring.

weight; chemical characteristics, such as composition and how sediments interact with the environment; and other factors, including sediment age, origin, distribution, and transport. By combining their knowledge of marine chemistry and physical oceanography, marine geologists help piece together information about how the Earth formed and how the movement of plates and continents results in events such as volcanoes and earthquakes. Also, marine geologists work with biologists and chemical oceanographers to learn more about historical climate records and animal and plant life by examining sediment and rock cores for fossils and analyzing sediment composition using radiocarbon dating and other methods.

Some of the major areas of specialization within the field of geological oceanography are described below:

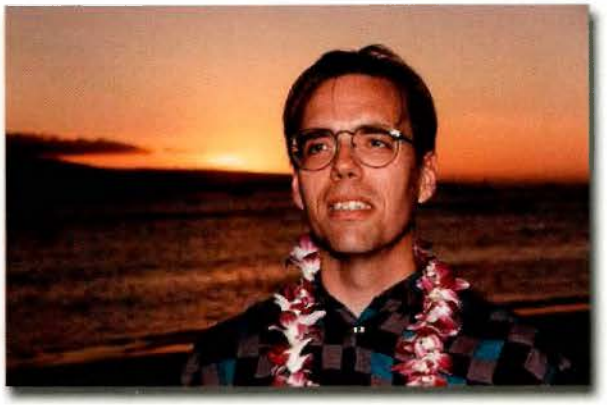
### *Seismology*

Marine seismologists map the Earth's interior structure by looking at changes in the way sound travels through the planet's various layers. These sound patterns appear as "waves." Seismic energy travels as an elastic wave, meaning that it can be reflected from the seafloor ("reflection") or it can penetrate through the seafloor and the layers within the Earth's interior and be bent as it travels ("refraction"). An important tool used by marine seismologists to "read" patterns of sound waves is the seismogram. You have probably seen examples of seismograms, which depict measurements of earthquake patterns. The instrument that records these measurements is called a seismometer. Though it's hard to imagine, there are thousands of microearthquakes beneath the ocean floor each day! Although marine seismology has told us many things about the Earth's surface and interior over the last couple of decades, more work is needed to answer important questions such as: What do mid-ocean ridges, fracture zones, and continental margins look like in 3-D, and how did they form? What is the Earth's deep interior really like? What are structures in the upper mantle of the

**10 years:** I expect to be doing pretty much the same kind of work, although I don't expect to be going to sea anymore. My interests are moving more toward data processing, visualization, and archiving, particularly with regard to the world wide web.

## Peter C. Griffith
### — biological oceanographer

**B.S., botany and zoology, Duke Univ.**
**M.S., marine, estuarine, and environmental science, Univ. of Maryland**
**Ph.D., ecology, Univ. of Georgia**



**current job:** I work in industry, at a company called North American Collection & Location by Satellite. We use satellites to measure and observe the natural environment and the activities of humans all over the world. My job title is general manager. This means I have two types of responsibilities. With regards to the work we do for our customers, I get to talk to scientists and business people about how my company can solve the problems that they are facing, using the technology that we already have or that we can develop. My other responsibilities are to see that our personnel have the resources they need to get their jobs done, and that the company operates within budget.

From my office in Landover, Md., I can tap into a virtual sea of information that includes the current location of a manatee taking a long summer swim from Florida to Long Island, the latest catch by fishing fleets in Peru, the number of volcanic earthquakes in Mexico, and the arrival of a tank container of hazardous chemicals in Chicago. We use our satellites in space and our computers on the ground to give our customers the information they need to achieve their scientific or business goals.

**key factor:** I grew up on a lake in Florida. If I wasn't snorkeling or looking for frogs, gallinules, and alligators, I was probably inside reading the latest issue of ***Popular Science*** from cover to cover. I learned to scuba dive during high school and loved the feeling of freedom as I floated among the creatures of the reefs. When I got to college, I was astonished to discover that I could actually study marine biology and biological oceanography. Spending eight months as an undergraduate student at the Duke University Marine Laboratory, surrounded by the marshes and islands of coastal North Carolina, convinced me to make this my life's work.

**like most:** I particularly enjoy hashing out a problem with someone, learning from them what they consider important, and devising a solution that is both technologically effective and economically feasible.

**like least:** It sometimes takes years to take a good idea and turn it into a fully realized, marketable product or service.

**relax:** I play with my kids, play jazz piano, read, swim, fish, or ride my bike. I've given up flying ultralight airplanes and I only occasionally get to scuba dive, but I do still teach race car driving.

**heroes/heroines:** I admire most those men and women, famous and unknown, who devote their best efforts to love and work.

**advice:** Learn as much as you can about how we think the universe works. This means studying math, physics, chemistry, computers, and biology. Learn at least one foreign language and learn how to write

Earth like, and what is their role in plate interactions?

### *Ocean Drilling*

The international Ocean Drilling Program (ODP), successor to the Deep Sea Drilling Project (DSDP) begun in 1968, is a partnership of scientists and governments created to explore the Earth's origin and evolution beneath the seafloor. Aboard the drill ship ***JOIDES Resolution,*** researchers from around the world gather samples of sediment and rock from below the ocean floor. (The "JOIDES" part of the ship's name stands for Joint Oceanographic Institutions for Deep Earth Sampling.)

Important discoveries made by the ODP include a new understanding of the causes and history of ice ages, the evolution of the continental margins, Earth's tectonic processes, marine sedimentation, and the origin and evolution of oceanic crust. Investigators involved in the ODP may specialize in sedimentology (the study of matter that settles to the bottom of the sea), paleontology (the study of fossil plants and animals and of the rock formations in which these fossils are found), petrology (the study of the origin, occurrence, structure, and composition of rocks), geochemistry, geophysics, and paleomagnetics.

As one might expect, these discoveries have led to new research questions. Drilling and sampling ocean sediment and crust will remain important to the field of oceanography. ODP officials predict that the program will assist and become more integrated with other earth science programs, such as the international program of mid-ocean Ridge InterDisciplinary Global Experiments (RIDGE), the Ocean Seismic Network, and the work of hydrologists and geochemists worldwide. In years to come, ocean drilling will tell us even more about earthquakes, global change, sea-level rise, climate, and ocean history.

### *Ocean Mining, Oil and Gas Exploration*

Ocean manganese nodules — small, dark, and

understandably, expressively, and persuasively. Ask questions all the time. Challenge assumptions. Remember, science is an exploration of a universe that is stranger than we can imagine.

**career opportunities:** Opportunities are always there for the bright, strongly motivated individual. It may take you another 10 years to school yourself to enter the scientific or technological workforce, and no one can predict what conditions will be at that time. Don't expect to find an easy, guaranteed career path. So, be flexible and innovative and do what you love to do.

**10 years:** In another 10 years I expect to be managing a team of engineers and business people who are working to devise solutions to environmental problems.

## Kay T. Ho
### — chemical oceanographer

**B.S., environmental toxicology, Univ. of California, Davis**
**M.S., environmental toxicology, Cornell Univ.**
**Ph.D., chemical oceanography, Univ. of Rhode Island**

**current job:** I work as an environmental research scientist at the Environmental Protection Agency laboratory in Narragansett, R.I. I develop methods for identifying toxic compounds in marine sediments. In sediments there are thousands of compounds, but usually only a few of them are toxic. Once we identify the compounds causing toxicity, we can then use that information to determine the source of the toxicants, prevent further pollution, and remediate the toxic sediments. I also work on methods to measure the ecological effects of toxicants.

**key factor:** Finding an undergraduate program in environmental toxicology. It showed me there was a way to combine my scientific knowledge with my interests in the environment.

**like most:** I like to think that what I do might make a difference in environmental regulation in this country.

**like least:** Bureaucracy, red tape, and how long it takes anything to happen in the government.

**relax:** I run, bodysurf, windsurf, garden, cook, knit, listen to music, and have big, late dinners with ferocious political arguments.

**heroes/heroines:** Rosa Parks for refusing to give up her seat on the bus. Georgia O'Keefe for painting so beautifully. Joni Mitchell for her voice and her lyrics.

**advice:** If you want to stay in the sciences and you want to have any control over the work you'll be performing, think about going all the way to a Ph.D.

**career opportunities:** I believe there will be opportunities in environmental sciences. Unfortunately, we (as a society), have a long way to go before we have a clean and healthy environment.

**10 years:** I think the big shift in the future will be to link our knowledge of what happens in the lab and at the organism level to what happens in the field. I think there will also be major changes in the way we relate information (Internet, etc.).

round-shaped nodules that contain manganese, nickel, copper, cobalt, and other minerals — are found along the floor of the Atlantic and Pacific oceans. The nodules were first discovered on the famous oceanographic *Challenger* expedition of the 1870s. Steel production requires millions of tons of manganese annually. Though ocean mining for manganese nodules has generated a great deal of interest, several factors have served as obstacles, including the difficult ocean terrain, the high cost, and political and international difficulties relating to its legality.

Similar problems associated with oil and gas exploration have caused international and national debate. While no one knows the exact extent of the oil and gas deposits in the ocean, oceanographers have made important discoveries about these potential reserves. The cost of exploring these sites is high. And, even if oil or gas reserves are found, recovering the resources is not always pursued due to the high cost of developing the site or other reasons. Partnerships between scientists and industry are important in the area of oil and gas exploration; oil companies constantly seek new reserves, while science makes it possible for companies to locate, analyze, and reach the resource. Current production takes place in the oceanic areas of continental margins, such as the Gulf of Mexico and the North Sea.

### *Coastal Geology*

An increasingly important area of marine geology is coastal geology. Throughout history, the human population has shown a tendency to settle along the world's 273,000 miles of coastline. The effects of humans inhabiting our shores and coastlines have become increasingly apparent. Coastal pollution and waste disposal are creating problems and costing government and industry billions of dollars in research and remediation efforts. Although the percentage of people living on the coast is expected to remain fairly constant over the next few decades, total numbers are expected to increase as population continues to increase.

## Anders W. Andren
### — aquatic chemist

**B.S., chemistry, Upsala College**
**M.S. and Ph.D., chemical oceanography, Florida State Univ.**

**current job:** I am professor of water chemistry in the Department of Civil and Environmental Engineering at the University of Wisconsin-Madison, where I teach and do research on aquatic chemistry. I am also director of the University of Wisconsin Sea Grant Institute. The Institute is involved in research, outreach, and educational activities related to our nation's Great Lakes and oceans.

**key factor:** An early interest in science combined with a fascination with the aquatic environment.

**like most:** Having the opportunity to work with the world's best scientists to better understand our oceans and Great Lakes. Having a chance to influence how our resources, both intellectual and financial, are used to provide guidance to the wise use of ocean and Great Lakes resources.

**like least:** That I don't spend more time out in the field doing research with my graduate students.

**relax:** Spend time with my family, play music (guitar and piano), cook gourmet foods, play sports (golf and tennis).

**heroes/heroines:** My mom and my dad.

**advice:** Science is a great and rewarding career. Get a good undergraduate degree in a basic science, such as math, physics, chemistry, biology, or geology. When you're in college, try to get a part-time job during the school year or summer in the laboratory of a professor who is in the field.

**career opportunities:** At the moment, we are seeing a slight decline in numbers of job openings. However, I believe this to be temporary as we move into the 21st century. The supply and demand will always be cyclical, just like in other science and engineering fields.

**10 years:** Teaching, research, and administration. I cannot think of a better situation where these opportunities exist.

## Rick Mohammed
### — physical oceanographer

**B.S., mathematics, Univ. of South Carolina**
**M.S., meteorology and oceanography, Naval Post Graduate School, Monterey (candidate)**

**current job:** My job as a Navy meteorology and oceanography (METOC) officer is to provide safe and accurate weather routing and forecasts for ships at sea. Additionally, METOC officers provide oceanographic data such as fronts, eddies, temperature vs. depth profiles, and a myriad of other services to ships and commands requesting them.

**key factor:** My interest in the ocean. I initially joined the Navy so that I could take advantage of the GI Bill and get money for college. I ended up going to college and getting my bachelor's degree while on active duty.

**like most:** The travel. The Navy allows one to visit many places. Also, I get to work with front-running technology and keep up to date on the latest advancements.

In addition to human effects on our shores, natural coastal processes such as rising sea level, erosion, and sediment transport, and storm-related events such as flooding, severe erosion, and storm overwash make our coastal areas dynamic environments. Often, humans react by attempting to protect structures situated along the coast, including homes, businesses, and roads, even when these structures are located on land forms, such as barrier beaches, that are "temporary" in a geologic sense of time. To protect these structures, coastal engineers have developed and constructed seawalls, jetties, groins, and bridges. More recently, natural or "soft solutions" such as constructed wetlands and salt marshes have been developed to slow the effects of coastal processes. Coastal geologists and coastal engineers, working with oceanographers from each of the disciplines, will be instrumental in forming policy and management options to minimize the conflicts between coastal development and natural processes.

### Physical Oceanography

Most oceanographers try to think of the world's oceans as one giant system, collectively known as the global ocean. But before space travel and the invention of satellites, it was very hard to actually observe the oceans on such a large scale. Pictures of the global ocean from space have given oceanographers important information about ocean currents, temperatures, and other properties. Satellites collect information around the clock and feed it back to earth — and individual laboratories and classrooms — in real time. This innovation has revolutionized oceanography and given researchers important information about weather and climate, circulation, and environmental problems, such as global warming, global circulation, the world's fisheries decline, and harmful algal blooms.

Perhaps more than any other group of oceanographers, physical oceanographers have benefited from satellite technology. Because they study the movement of the oceans and the forces that cause motion, such as winds, waves, and

## Carol J. Zimmerman
### — marine geophysicist

**B.S., physics, Rensselaer Polytechnic Institute**
**M.S. and Ph.D., oceanography and limnology, Univ. of Wisconsin**

**current job:** I am a geophysical associate with Exxon Exploration Company in Houston, Texas. I do special data processing, modeling, and interpretation to support the oil exploration effort offshore of West Africa.

**key factor:** As an undergraduate, I studied a good, basic science — physics. I enjoyed learning the fundamental principles that make our world tick. Later, I decided to apply those principles to the ocean environment. I became interested in exploring for mineral deposits under the sea, then a largely unexploited resource.

**like most:** After enjoying many years of travel, I have settled down to family life in Houston. Now, I enjoy my work the most when I have played a key part in drilling a successful well. There always is much excitement when a well is going down, and there is usually a big celebration when a discovery is made. I also enjoy attending professional society meetings and learning about the new technology in my field.

**like least:** I'll never know everything there is to know about my field. There isn't a finite end to the knowledge that can be gained about the ocean and atmosphere.

**relax:** I enjoy music, movies, reading, scuba diving, and art.

**heroes/heroines:** Gen. Colin Powell. He's a man who started from humble beginnings and became a great leader and an inspiration to our country.

**advice:** Take a lot of math courses. Mathematics will prove to be one of the most valuable tools required for any science. It is never too late to start taking math courses no matter what your level is. Even if you're a senior in high school getting ready to graduate, the first course you should sign up for is a math course.

**career opportunities:** As a naval oceanographer, the opportunities for a career move up and down with the emphasis that is put on the military at the time. I believe that naval oceanography will always have a future. There are too many lives that are dependent on the job and service that we provide for us to go away.

**10 years:** I expect to still be supporting the US Navy and other navies throughout the world by providing the most accurate data available and thus assisting them to make safe tactical decisions.

tides, they must look at the ocean from a "big picture" perspective. Shipboard measurements and the development of instruments such as computer programmable buoys that can be left at sea for long periods of time were huge advances for the field of physical oceanography and continue to be important tools, but satellites offer perspectives that early oceanographers may never have dreamed of. Imagine the discoveries Benjamin Franklin, the first person to plot the course of the Gulf Stream, could have made if he'd had access to satellite data!

Physical oceanographers study the interaction between the ocean and its boundaries — land, seafloor, and atmosphere — and the relationship between the sea, weather, and climate. Questions about how the oceans work in a physical sense include investigations into water qualities such as temperature, salinity, density, and influential factors such as wind speed, air temperature, tides, and interaction with nearby land and underwater formations.

Physical oceanographers seek to understand why, where, and how water moves, on all space and time scales. They are interested, too, in the consequences of these movements. Some physical oceanographers are theoreticians and use computer models to answer questions and form hypotheses about oceanographic processes. Others use observations and, increasingly, satellite observations. Understanding the global ocean requires a close partnership between theory, observations, and experiments.

Often, physical oceanographers work with their biological, chemical, and geological colleagues. Understanding the way the ocean works, physically, supplies oceanographers in the biological, geological, chemical, or engineering disciplines with important details they need to answer questions. The physical properties of the ocean are intimately linked to the biology and chemistry of the ocean, and vice-versa.

For example, physical oceanographers are currently working with biological oceanographers and ocean engineers in a multi-institution, multi-agency research initiative known as

**like least:** Sometimes I am not able to do the job as well as I would like before the deadline hits. There can be a lot of stress because of changing priorities. On the other hand, it can be exciting not knowing what will happen next.

**relax:** I do aerobic dance exercises and soothe my aching muscles afterwards in a hot tub. Keeping fit helps me stay sharp mentally and also alleviates the stress of juggling a career and family life.

**heroes/heroines:** Oil and gas exploration is a risky business. I meet people every day who could be heroes/heroines. These are people who are not afraid to take calculated risks.

**advice:** You will need at least a master's degree in geology or geophysics. Go for it. Learn all you can and stay focused on your goals. Don't give up. Persistence often wins out over innate talent.

**career opportunities:** Increasing, definitely. There is a serious shortage of trained people in the field.

**10 years:** Although I will be eligible for retirement from Exxon by then, I may not want to retire when the time comes. I may stay within Exxon as a geophysical advisor, or I may choose to be a consultant for the larger geophysical community.

## Frank R. Hall
### — geological oceanographer

**B.A., earth science, Kean Univ.**
**M.S., geology, Lehigh Univ.**
**Ph.D., oceanography, Univ. of Rhode Island**

**current job:** I am an assistant professor in the Department of Geology and Geophysics at the University of New Orleans in Louisiana. My title is "geoscience educator." In this role, I work with pre-service and in-service teachers who are interested in teaching science, especially earth science. This is a position that I find personally satisfying as I feel that I am making a difference in the education of future generations of scientists.

I am also active in research. My research involves the examination of particles that fall to the seafloor through the ocean. Mainly, I focus my research in the Canadian Arctic, an area influenced by both the oceans as well as by icebergs that originate on land.

**key factor:** I find my present work as an educator to be very challenging. I come from a family of teachers. My father was a college professor and my mother was a junior high school teacher. I was raised with the idea that education is very important. When given the opportunity to make a difference in preparing teachers, it was a challenge that I could not turn down.

**like most:** I like the opportunity oceanography has given me to meet and work with scientists from many parts of the world. I especially like having the opportunity to visit them in their homes and learn about their culture and customs.

**like least:** Scientific research requires money. To be an active participant, one must be able to raise funds. That is often very difficult. Part of the process of raising funds requires the review of your proposals by anonymous colleagues. They can at times be unkind, making this part of being a scientist frustrating.

***(continued on page 32)***

ECOHAB (short for ecology of harmful algal blooms). The Gulf of Maine portion of the ECOHAB project is seeking to determine the source and distribution of *Alexandrium* cells (*Alexandrium* is the organism that causes paralytic shellfish poisoning, PSP, and is considered one of several harmful algal blooms, once referred to as "red tide."), and the role of ocean currents and plumes in transporting the cells to nearshore areas where they "bloom" and become toxic, poisoning shellfish. The role of physical oceanographers is to assist with oceanographic and satellite measurements, computer modeling, and instrument design, deployment, and recovery. The collaboration continues, with the ultimate goal of, one day, being able to predict toxic bloom events.

### Chemical Oceanography

The ocean has been referred to as a "chemical soup" because it contains many chemical compounds, elements, gases, minerals, and organic and particulate matter. While water is the most plentiful ingredient, salts are among the most important. Amazingly, despite the major changes that have taken place on Earth throughout history — continental collisions, land formations, glaciation — the basic composition of seawater has remained relatively constant for millions of years.

Chemical oceanographers, also called marine chemists, marine geochemists, or even marine biogeochemists, may study one or a combination of the following: formation of seawater and seafloor sediments, relationships between chemical compounds (both organic and inorganic), how chemical inputs to the ocean (including pollution) affect it, and how the chemistry of the ocean affects or is affected by biological, geological, and physical factors. As with the other disciplines of oceanography, chemical oceanographers rely on and interact with researchers from the other disciplines.

One important aspect of chemical oceanography is the study of pollutants. This work may lead chemical oceanographers to the deep ocean, coastal bays and estuaries, or inland rivers, streams, and lakes. Sources of pollutants range from the obvious (sewage, oil or fuels, ocean dumping) to sources that are harder to detect or trace (agricultural or lawn runoff containing chemical fertilizers, leaking septic systems, road runoff, or storm drain overflows). Chemical oceanographers study the impact of such pollutants by examining how they interact with seawater, marine life, and sediments. Chemicals and pollutants introduced to a marine environment may behave very differently depending on environmental conditions such as salinity, wind, rainfall, temperature, and transport methods. Transport methods include land-based (for example, surface runoff or groundwater), water-based (rivers and streams), and atmosphere-based (rain and dust).

The study of carbon and its role in global climate change has captured the attention of chemical oceanographers for decades. Since the industrialization of the 18th century, researchers estimate that the amount of carbon dioxide in the atmosphere has increased by 25 percent. Although the scientific debate continues over whether the increase in atmospheric carbon dioxide has caused global warming or vice versa, it is generally accepted that modern society has added to the amount of carbon dioxide in the atmosphere.

What does all this mean? Since carbon dioxide absorbs infrared radiation (heat), an increase in carbon dioxide in the atmosphere would keep the heat from escaping into space. This would cause the Earth to warm up just as a greenhouse holds heat, thus the popular term "greenhouse effect." Chemical oceanographers are working to understand the ocean's role in this and other theories related to global climate change.

Modern society's rapid technological advances, including the development of complex chemical compounds and processes used to produce and manufacture energy, food, clothing, medicine, and other products, have created a need for chemical oceanographers. In the quest for bigger, stronger, faster, more, the costs of "improvements" often get overlooked. For example, the disposal of waste that results from products and by-products can be a problem in itself. Who would have thought that household cleaning products, fertilizers, pesticides, boat paints, and leaded fuel — all products that saved time, worked better, and often cost less — could have contributed to the degradation of many marine and coastal areas? Fortunately, researchers in many oceanographic disciplines and related areas, including marine chemists, have worked together to improve our understanding of such impacts, which has, in turn, led to improved controls, regulations, testing methods, and ultimately, safer products.

The work of chemical oceanographers will continue to provide answers to important questions. For example, the use of the oceans for waste disposal and as a source for drugs and minerals will require cooperative research between ocean chemists, biologists, and geologists. It is the work of marine chemists that aids ocean engineers in the development of instruments, vessels, and ocean vehicles that, in turn, improve the ability of researchers of all oceanographic disciplines to go to sea, collect data, and discover previously unknown formations, marine life, and phenomena.

As the population discovers new ways to use the oceans — be it for food, transportation, energy, or waste disposal — chemical oceanographers will play an important role in improving our knowledge about the impact of these activities on the ocean and its ability to sustain them. ●

# Ocean Engineering

**The field of ocean engineering** provides an important link between the other oceanographic disciplines such as marine biology, chemical and physical oceanography, and marine geology and geophysics. Just as the interests of oceanographers have driven the demand for the design skills and technical expertise of ocean engineers, the innovations in instrumentation and equipment design made by ocean engineers have revolutionized the field of oceanography. This is especially true within the last three decades.

The invention of thousands of oceanographic instruments and devices has changed the way oceanographers study the oceans and coasts. Examples include: computer- and satellite-linked buoys and floats, sediment traps, ocean seismometers (instruments that measure seafloor movement in a manner similar to the way seismographs measure earthquake activity on land), underwater video equipment, acoustic measuring devices (instruments that make it possible to "sense" underwater objects and seafloor formations), and underwater vehicles, including submersibles and remotely operated vehicles (ROVs). Information that once took years to compile, and that frequently involved sampling in harsh weather conditions, can now be accomplished in minutes, often from remote locations, including ships and laboratories. The innovations of ocean engineers have enabled oceanographers to travel farther offshore and deeper into the sea, and to stay there for longer periods of time. Because of ocean engineers, major oceanographic discoveries — including hydrothermal vents, ocean volcanoes, thousands of miles of underwater mountain chains, "new" species, and biological, chemical, geographical, and physical processes and phenomena — have been made.

Ocean engineering is actually a combination of several types of engineering: a mix of mechanical, electrical, civil, acoustical, and chemical engineering techniques and skills, coupled with a basic understanding of how the oceans work. The importance of working in partnerships with oceanographers from other disciplines is critical, as the challenge of working in the ocean environ-

## Langley R. Gace
— ocean engineer

**B.S., physics, Bates College**
**M.S., ocean engineering, Univ. of New Hampshire**

**current job:** I am an ocean engineer at Ocean Spar Technologies on Bainbridge Island, Wash. Our company develops and sells high performance offshore aquaculture cages to customers worldwide. Most of my time is spent developing computer models of cages and learning how they will behave in the offshore environment. I also spend some of my time out at sea inspecting our products after they have been installed and visiting potential sites for raising fish with customers.

**key factor:** The ocean has always fascinated me. Ocean engineering seemed like the perfect way to combine my love of the sea and my physics degree from college. Also, my great uncle Athelston Spilhaus, who helped start Sea Grant, was an ocean engineer. While growing up I would hear about the marvelous projects he was working on, so it seemed quite natural for me to head in this direction.

**like most:** The fact that we are producing a product that ultimately provides food to the masses and doing it in an environmentally conscientious fashion.

**like least:** The industry's lack of vision sometimes frustrates me. Fish farmers are very wary when it comes to trying new ideas.

**relax:** I love to go sailing. I also enjoy golf and working around the house and garden with my wife.

**heroes/heroines:** I have two heroes. One I have mentioned: Dr. Athelston Spilhaus. His creativity was simply amazing. My other hero is anyone who goes out and makes the very best of each day despite circumstances.

**advice:** Don't go directly into ocean engineering. Get a mechanical or civil engineering degree first. It is there that you learn the basics. Though I was a physics major, I took the basic engineering courses before I went to grad school and that made all the difference.

**career opportunities:** The job potential in aquaculture is strong for engineers. As the demand for offshore rather than nearshore cages has increased, so has the need for talented engineers to build structures that will survive out there.

**10 years:** I would still like to be involved in offshore aquaculture in some capacity. I hope that the industry will have matured some by then so that there will be different challenges.

ment requires a range of backgrounds and skills.

The expertise of ocean engineers is invaluable to oceanographers interested in measuring or studying various aspects of the ocean. For example, programmable buoys that can remain at sea for long periods of time have helped physical oceanographers study currents and weather in many locations at once. In addition, the data gathered by these buoys can be relayed back to a laboratory located on a ship or on land, giving the researcher "real-time" data. This is especially important for marine meteorologists.

Not only do ocean engineers design and build instruments that must stand up to the wear and tear of frequent use, they must design instruments that will survive the harsh conditions of the ocean environment. Salt water is highly corrosive to many materials, and high winds, waves, currents, severe storms, and marine life fouling (such as barnacles) must also be factored into design plans. It has even been said that the marine environment is more hostile than outer space!

In addition to ocean engineers, technicians play a key role in maintaining and preparing the equipment. It is the responsibility of technicians to make sure that instruments are functioning properly, that they are recording the measurements they were designed to, and, in some cases, that the information being recorded is being relayed back to satellites or computers that may be hundreds or even thousands of miles away.

Coastal engineering has become an increasingly important part of ocean engineering. With more and more people living or working at or near the world's coasts, problems associated with coastal development, such as pollution and waste disposal, will require the expertise and innovation of coastal engineers. For example, increasing the capacity of a coastal community to handle the sewage and garbage generated by a growing population requires careful attention to the effect disposal methods will have on the adjacent water bodies. What may work for an oceanside community may not work for a lakefront or riverfront community. Also, waves, rising sea level, and

## Carmen G. Borda
### — naval architect

**B.S., civil engineering, Virginia Polytechnic Institute and State Univ.**

**current job:** I am a naval architect working at the Naval Surface Warfare Center Carderock Division in Bethesda, Md. This is a Navy research and development facility with large towing basins, water tunnels, and wood and metal shops. My job entails planning, organizing, implementing, and supervising fundamental and applied research projects. The projects with which I am associated include the model scale evaluation of designs of ships, submarines, and other craft as well as the associated propulsion systems.

**key factor:** While in high school, I did exceptionally well in the higher level math and science classes. My father, an engineer, talked me into pursuing an engineering degree in college. This was very difficult, but I also found it challenging and exciting.

**like most:** I like the challenge of devising an experimental or analytical method of evaluation. It requires creativity. I am continuously thinking and learning because of the diversity of projects.

**like least:** I do not like meetings.

**relax:** I have two school-aged children engaged in a variety of activities, so I don't do a lot of relaxing. However, I always make time to exercise and read. We enjoy vacations at the beach, swimming, biking, picnics, camping, hiking, and ethnic foods.

**heroes/heroines:** My heroes are my parents, because they provided me with a sense of self importance, dignity, moral and spiritual values, and direction. They taught me that through hard work I could achieve whatever I desired.

**advice:** Read in your spare time. Take as many math and science classes as you can. Never be afraid to ask a question. Strive to do your best, because the harder you work the more choices you will have. A good education is the key to a world of opportunities.

**career opportunities:** We will always need intelligent, well-educated individuals with technical college degrees.

**10 years:** In 10 years I will be two years away from retirement. Then I expect to spend a lot more time relaxing with my family. I will spend my time reading, traveling, swimming, biking, and exercising. I hope to buy a house close to the beach.

## William Childress Green
### — environmental analyst

**A.A.S., marine biology and oceanography, Southern Maine Tech. College**
**B.A., biology, Univ. of South Florida**
**M.S., environmental studies, Yale Univ.**

**current job:** I serve as environmental analyst for Guilford, Conn. With that title comes a myriad of responsibilities.

My primary job is to administer the town's Water Pollution Control Program. I gather and analyze surface and groundwater samples for certain contaminants, track pollution sources, and assure that they are abated. As part of Guilford's Pollution Control Program,

storms have a significant impact on coastlines, often causing erosion and loss of coastal property. In efforts to protect coastal structures, coastal engineers are tasked with designing and creating ways to lessen the impact of storms and other natural shoreline processes.

The oil industry, military, and marine navigation fields also require ocean engineering skills. Each of these sectors directly impacts our lifestyle in some way, be it a source of energy, transportation, or our nation's defense. The work of ocean engineers plays an important role in each of these employment sectors. Because technology is central to the field of ocean engineering, future career prospects seem promising. And, as the role of the ocean continues to gain the interest of business, government, and the private sector, the demand for ocean engineers should grow.

Experts in the education and engineering fields regard ocean engineering as a very systems-oriented field because of its interdisciplinary nature. Without the expertise of ocean engineers, oceanography would be many years behind in terms of what we know about the ocean system and its impacts on our daily lives. ●

it is my responsibility to monitor coastal water quality trends. I conduct annual surveys of commercial/industrial and residential properties to assure compliance with state and local health and water pollution regulations.

In my capacity as an environmental official, I often act as an advisor to our local Inland Wetland Commission. When requested by the Commission, I respond to matters that entail a review and comments on wetland assessments/statements, proposals, etc. presented to the Commission by land developers.

In addition, I assist the town's departments and commissions with technical aspects of applications when they apply for permits from local, state, and federal agencies.

**key factor:** As a midwestern high school senior, my career inclination was to be a wildlife biologist. However, my interest quickly changed when I visited New England for the first time. The marine environment was mysterious and so different from my familiar freshwater surroundings that it triggered within me an interest I had to pursue.

**like most:** I truly enjoy being directly involved with, and responsible for, changes that make a positive difference in our natural environment.

**like least:** What I have the most difficulty with is the frustration of not being able to do all that should be done. There aren't enough hours in a day.

**relax:** Fishing, shellfishing, playing billiards, and gardening.

**heroes/heroines:** I have numerous personal heroes/heroines. The first would have to be my father, who taught me to appreciate nature.

Several professors of mine I would also consider heroes, particularly Bob Goode, Southern Maine: Larry Brown, South Florida; and Tom Siccama and Karl Turekian, Yale. Their knowledge and accomplishments are inspiring to me. Their dedication to students and to their own work has made an impression on me.

Last and by no means least, two more great influences on my life's work are Eugenie Clark and Rachel Carson.

**advice:** Get involved now! Sign up for, attend, and participate in seminars related to your interest. Use resources such as local, state, and national organizations; private companies; the Internet; and any other avenues available to become informed, connected, and excited about what is going on in your potential field. Have fun, keep an open mind, meet people who are involved in your area of interest and pick their brains.

**career opportunities:** Career opportunities are increasing. Development pressures/encroachments on sensitive coastal and upland areas, habitat loss, and point and non-point sources of pollution are adversely affecting environmental quality almost everywhere. I believe the demand for environmental scientists will increase as the complexity of our environmental problems increase.

**10 years:** I will be semiretired, however I anticipate being an active volunteer in my community, working with environmental groups and helping students, much the same as I do now.

## Joanne McCaffrey
### — ocean engineer

**B.S., ocean engineering, US Coast Guard Academy**
**M.S., ocean engineering, Univ. of Rhode Island**

**current job:** I'm the facilities engineer for the Coast Guard Integrated Support Command in Portsmouth, Va. I have a staff of 44 military and civilian carpenters, electricians, mechanics, plumbers, environmental specialists, and grounds maintenance personnel responsible for the care and upkeep of the 187-acre/19-building facility and its extensive waterfront. My job is to supervise the facilities engineering staff, ensure they have the tools and guidance they need to succeed, and prioritize their work.


**key factor:** Although I did not do exceptionally well in math in high school, I began to excel in it when I went to college at the US Coast Guard Academy. I liked the idea of applying math to solve practical problems, so I looked into the engineering majors offered at the Academy. Ocean engineering sounded very interesting and I thought it would pose a real challenge. Pursuing a degree in engineering was tough but I'm glad I did it.

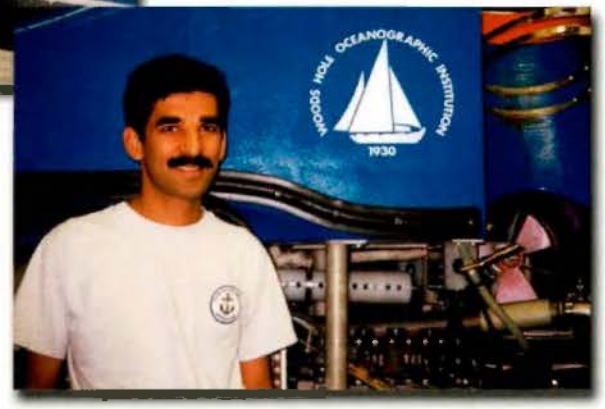
**like most:** Being a Coast Guard officer is fascinating and very challenging. I am assigned to a new job in a new place every three to four years! My family and I have lived in four different states and I have had a wide and varied array of assignments.

**like least:** Working with people who would rather complain than look for the good in a project or assignment.

**relax:** I have three busy children so I don't do a lot of relaxing! My husband and I are active in our community's youth sports programs and really love coaching and watching our children play sports and grow.

**heroes/heroines:** My parents are my heroes. They always had time for me and my three siblings. My mom told me I could do or be anything I wanted. She was the one who told me the service academies would be accepting women for the first time in 1976 and encouraged me to apply to be in the first class of women.

**advice:** Always work hard at all that you do. When you get good grades in high school, you decide where to go to college. If you get mediocre grades, you have to go to the school that accepts you. The harder you work, the more choices you have.




**career opportunities:** The Coast Guard has plenty of openings for qualified people. You can become an officer after attending college or you can apply to the Academy. The Academy is difficult to get into, but well worth the effort. The opportunities for women in the military are fantastic.

**10 years:** I will probably be retired from the Coast Guard (you can retire after 20 years of service). I'll pursue a second career in engineering or teaching. I'm hoping to travel and spend more time "smelling the roses."

## Hanumant Singh
### — ocean engineer

**B.S., computer science/electronics and computer engineering, George Mason Univ.**
**Ph.D., oceanographic engineering, Massachusetts Institute of Technology/Woods Hole Oceanographic Institution Joint Program**

**current job:** I am an assistant scientist at the Woods Hole Oceanographic Institution. I work in the Deep Submergence Laboratory, which was founded by Robert Ballard, the scientist best known for finding the ***Titanic***. I work with underwater robots — specifically using underwater robots to do imaging. I often go out to sea with my robots to map out ancient shipwrecks, hydrothermal vent structures, and other oceanographic phenomena of interest.

**key factor:** The amount of fun I can have while making a difference to the quality of life for everyone on this planet. I go to sea with my robots and use them to do work that makes a difference in our understanding of the oceans and ultimately our planet. It's extremely satisfying.

**like most:** I have the freedom to do exactly what I want. Nobody can tell me what to do. I choose to work on matters that I deem interesting. I also think teaching and working with students is immensely satisfying and fun.

**like least:** The freedom I have is based on my ability to convince funding organizations that what I am doing is relevant and important to society. This job is not easy and I have to write a lot of proposals so that I can keep

my own research (and that of my engineers and students) funded.

**relax:** I windsurf, i write, and I run. Windsurfing is a good way of understanding the interactions at the water-sea interface. I write fiction as well as articles about my expeditions and research. I run to keep fit and because it helps me focus my thoughts. I ran the Boston Marathon in 1994 and one of these years plan on completing a marathon in under three hours.

**heroes/heroines:** Leonardo da Vinci for the breadth of his genius and Mahatma Gandhi for showing the world the path of non-violence.

**advice:** Study hard with an emphasis on the fundamentals associated with the physical and mathematical sciences.

**career opportunities:** They have remained roughly constant over the last five years. With 70 percent of the planet covered with water and with our growing understanding of the roie of the oceans in governing climate, our field will definitely maintain its importance.

**10 years:** Having even more fun! I hope that my students will be distinguished scientists, engineers, and professors all working together in related fields. Our work will provide a crucial insight into important questions such as those to do with global warming as well as insight into engineering questions on autonomous behavior and systems.

## Joseph H. Comer III
### — marine architect

**B.S.E., naval architecture and marine engineering, Univ. of Michigan**

**current job:** I am Vice President of Production Engineering at the Halter Marine Group Inc. in Gulfport, Miss. I am responsible for departmental management of the development of designs for various marine vehicles. Our group enters the design spiral at any point from contract design to the preparation of detailed production drawings. We utilize many aspects of CAD/CAM technology to produce these designs.

**key factor:** At a very early age I fell in love with the saltwater environment and boating. As I got older this inspired the desire to live and work near coastal areas.

**like most:** Living in a lovely coastal area where my personal enjoyment of marine activities and my professional goals are synonymous. Being constantly involved with the production of marine designs.

**like least:** The pressures of time and budget and applying those pressures to our employees.

**relax:** Reading, sailing (both in competition and for pleasure), water skiing, duck hunting, fishing, and just messing around with boats.

**heroes/heroines:** Frontiersmen, seamen, adventurers. The people, even today, who are willing to go the extra mile to accomplish a goal or task.

**advice:** Find out as much as you can about the marine industry by visiting companies and related universities, observing marine products, and reading.

**career opportunities:** The sea is our last great frontier; naval architects and marine engineers will lead the way.

**10 years:** Sailing!

## Heidi Nepf
### — environmental engineer

**B.S., mechanical engineering, Bucknell Univ.**
**M.S. and Ph.D., civil and environmental engineering, Stanford Univ.**

**current job:** As a professor of environmental engineering at the Massachusetts Institute of Technology, I conduct research and teach courses in environmental hydrodynamics (the study of water motion). My ocean work mostly deals with flow through and around aquatic vegetation like salt marsh grasses and eelgrass. I examine how the plants impact water motion. I work in collaboration with an eelgrass biologist who studies how the water motion affects the plants.

**key factor:** Because I enjoyed science and mathematics, my father and grandfather encouraged me to pursue an engineering degree. During my sophomore year I took a course in fluid mechanics where we did a lot of experiments. The professor was very enthusiastic, and I really loved working in the laboratory — using my hands and brain together.

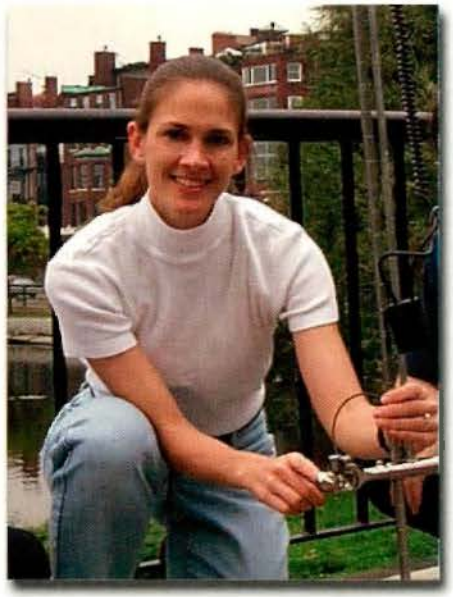
**like most:** I love designing experiments to answer scientific questions because I like solving puzzles. Creating a good experiment takes a lot of creativity. I especially enjoy using dyes or fluorescent particles to help me see how the water is moving.

**like least:** I hate meetings. Some of my colleagues can be long-winded.

**relax:** I enjoy mountain biking and hiking, going to the movies, and taking long walks. I also like mystery novels.

**heroes/heroines:** I admire strong women who lead elegant and interesting lives without reservation or hesitation, including Eleanor Roosevelt, Katharine Hepburn, Marie Curie, and Isak Dinesen.

**advice:** Get a good background in math and science, especially laboratory subjects. To learn more about environmental science/engineering you can volunteer with a local river or park association.



**career opportunities:** We will always need environmental experts, especially ones with a good understanding of how society can and should balance its need for development against the needs of environmental protection.

**10 years:** I will still be active in field and laboratory research. I love research. The ideas and activities are always evolving and changing. And I love environmental research, because its goals are ultimately to protect our natural resources and benefit society.

## John Buck
### — electrical engineer

**B.S., electrical engineering, Massachusetts institute of Technology**
**B.S., English literature, MIT**
**M.S. and Ph.D., electrical engineering and oceanography, MIT/Woods Hole Oceanographic Institution Joint Program**

**current job:** I am an assistant professor of electrical and computer engineering at the Dartmouth campus of the University of Massachusetts. I am also an associate fellow of our campus' Center for Marine Science and Technology (CMAST), an interdisciplinary oceanography lab. During the school year I teach undergraduate and graduate courses in electrical engineering, as well as supervise graduate students. In addition to guiding them in doing their thesis research, I try to teach them the process of doing research in general, so they will be prepared to pursue their own projects when they graduate.

In my own research, I study how sound travels underwater and how best to analyze underwater sounds, whether they are made by humans or marine mammals. My largest research grant is from the National Science Foundation to study the sounds made by dolphins and whales and to develop new tools to help biologists track and identify these animals underwater.

**key factor:** UMass Dartmouth is a good fit for me professionally in several ways. The campus has a history of strong undergraduate education, which matches well with my interest in teaching and working with students. In addition, our department has a history of research in marine-oriented applications of electrical engineering.

**like most:** I find oceanography an exciting field because it combines intellectual challenges with physical adventure. I also enjoy the practical aspect of the work. The ocean is always the ultimate proving ground — a concrete test for our ideas. Good ideas work, bad ones send you back to the drawing board.

I like the freedom and responsibility in choosing my own work in the academic environment. I can choose the problems I want to study, the students I want to work with, the classes I want to teach, etc. This means that I spend almost all of my time doing things I enjoy doing, and that I am doing them because I want to do them.

**like least:** There is too much of it. As I said above, I really like almost every part of my job. However, any one of its components contains enough challenges and problems that it could be a full-time job in itself. Things can be very hectic at times, especially when deadlines from two different aspects of my job collide, such as having to get a paper to a journal during the last week of the semester.

**relax:** I enjoy playing sports to relax, mainly ice hockey, lacrosse, jogging, swimming, and ultimate frisbee. Finding time for some sort of physical exercise almost every day is important for my health and sanity.

Dartmouth is only about an hour from Boston, so I am able to enjoy the cultural benefits of the city. Some of the events I attend frequently are the Boston Symphony Orchestra, the Boston Baroque ensemble, and rock shows in local clubs. I also try to make time to read good books.

**heroes/heroines:** Two of my heroes are St. Thomas Becket and St. Thomas More. Both were men with the moral courage to stand up for their beliefs in the face of public opinion.

**advice:** You can't learn enough math. No matter what field you are in, math will always be useful. Two other very important skills are the ability to write well and the ability to program a computer. I think in 10 years it will be very hard to do research in most of marine science without being able to program a computer at some level.

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# Related Fields

There are many jobs in the field of marine science that do not fit into the categories of marine biology, oceanography, or ocean engineering. Instead, these jobs may fit more than one category, or they may overlap other fields, such as education, communication, economics, seagoing careers, or business.

Many of these jobs are highly specialized and require very different educational backgrounds, experiences, and skills. Some of the jobs may be unique to the people who do them. In other words, they may have started their own business or created their position because they perceived a need for their expertise.

Some characteristics shared by people in virtually all marine-related careers include a love of the marine environment, a respect for the way the ocean works, and a sense of curiosity. Many people in the marine sciences describe a feeling of accomplishment or satisfaction about their work, knowing that being involved in their field has or will make a difference for present and future generations. Others like the sense of pioneering discovery, given the fact that much remains to be learned about the way the ocean works and the organisms that inhabit it.

There are countless possibilities for a marine-related career: marine educator, science writer, filmmaker, photographer, ecotourism guide, park ranger, beach superintendent, maritime or environmental lawyer, coastal or ocean policy experts, aquavet (veterinarians that specialize in marine or aquatic animals), economist, marine archaeologist, marine historian, fundraiser or spokesperson, aquaculturist, manager of an agency specializing in marine or freshwater issues, marina manager, ship's captain or mate, environmental planner, manager of a land conservation organization or land trust, botanist, computer specialist with a marine or environmental organization, ecologist, hatchery specialist, landscape or maritime architect, and so on.

While we certainly won't attempt to list all of the possibilities, it's probably safe to say that you can combine your interest in the ocean or

## Sonya Wood Mahler
### — environmental educator

**B.S., marine biology/physics, Auburn Univ.**
**B.S., secondary science education, Auburn Univ.**
**M.S., environmental education/natural resources, Univ. of Wisconsin, Stevens Point**

**current job:** I am a marine extension agent for Florida Sea Grant. My office is in Pensacola, but I work throughout Escambia and Santa Rosa counties. I'm a marine biologist with a twist. I do a little research and a lot of education. Working with both adults and youth, I coordinate a variety of marine and coastal programs. This includes organizing beach cleanups and underwater cleanups, marine mammal rescues, sea turtle monitoring efforts, manatee dive trips, the fishing line recycling program, 4-H marine camps, estuary canoe trips, and a program for coastal residents called ***When the Gulf is Your Backyard***. I distribute a quarterly marine education newsletter entitled ***Turning the Tide*** and other Sea Grant and Extension Service publications.

**key factor:** I wanted to work with the marine and coastal environment. I grew up on the Gulf coast and I wanted to help other residents appreciate and protect it. That was far more important to me than how much I would make. I worked in marine mammal research and taught high school marine biology before finding this perfect niche for me called marine extension. I bring the research to a wide audience in a way that they can understand it and use it.

**like most:** The tremendous flexibility and variety. The opportunity to develop programs and projects to meet the needs of the community. I get paid to do what I love to do and live in Paradise!

**like least:** This is definitely not a nine-to-five job. I work a lot of nights and weekends because that is when the audiences are available. There are many 60-hour weeks.

**relax:** Bike riding, kayaking, windsurfing, waterskiing. I do a lot of photography, both underwater and above. I enjoy travel, theater, Samoyeds, blues and country music, shrimp, and dark chocolate.

**heroes/heroines:** Edward Abbey, Bev Doolittle, Jacques Cousteau, Sylvia Earle, Charles and Ann Morrow Lindbergh, Richard Wilke, and my parents, Frank and Frankie, who are outstanding educators.

**advice:** Get lots of field experience (on weekends, in the summer, as a volunteer) to make sure this is what you enjoy and to develop your skills. Also, get experience in public speaking, writing, computers, graphics, photography, lab work, scuba or skin diving, and the identification of coastal creatures and native plants.

freshwater with many other fields, hobbies, or specialties to design a potential career.

As many different career opportunities as there are in the marine field, especially the "related fields," there are almost as many different pathways to achieving such a career. Underwater filmmaker Bill Lovin's career path is one example. His advice to aspiring underwater filmmakers: "First, learn to be the best diver you can be, completely at home in the water. Second, don't major in film or television in college. Take marine biology or journalism or even business. Learn a lot about a lot of things. . . You will have to make your job because there are few (perhaps no) jobs out there at any given time."

Similar advice is offered by William Spitzer, director of education at the New England Aquarium, who was trained as an academic scientist and holds a Ph.D. "In working in science education," he says, "it really does help to understand science from the point of view of a scientist. However, I also had to learn a lot of staff and project management skills along the way to be effective in my job. I created my own career path based on my interests in science, social and community service and education, and the environment. My advice is to follow your heart; find ways to pursue what you care most about and create your own path."

If you like to write and you have a love for the water, ocean, or environment, a career in environmental reporting, science or technical writing, communications, or public relations may be worth exploring. If you are a "people person," enjoy teaching and public speaking, and don't mind working long hours, a career in marine education may be for you. Even in the field of education, you can choose between formal education (a classroom or academic setting) and informal education (for example, aquaria, museums, nature or science centers, parks, or wildlife refuges).

If you love fish and have considered a career as a doctor, perhaps you should consider becoming an aquavet or an aquaculture veterinarian, as Myron Kebus of Wisconsin did (read

**career opportunities:** The number of positions like mine with federal and state agencies has decreased slightly. I think the future will see increasing competition for positions in environmental fields.

**10 years:** I hope to be working with Sea Grant in some coastal state as an agent or specialist.

## Bill Lovin
### — underwater filmmaker

**B.A., journalism, Univ. of North Carolina, Chapel Hill**

**current job:** I produce natural history, educational, environmental, and entertainment films and videos about the marine world for television and for the classroom. I have my own company and do a little of everything — diving and shooting, editing, writing scripts. I live 150 miles from the coast in Chapel Hill, N.C., but my work takes me all over the world.

**key factor:** Realizing that it was possible. Lots of people think this would be a wonderful thing to do, but most think that it isn't possible for them. You have to decide that you can do it and be willing to put in the work and time required.

**like most:** Filmmaking is an art and like any artist, I get satisfaction from the act of creating something I believe in.

**like least:** The need to sell myself. I hate to self-promote and wheel and deal with "suits."

**relax:** I work all the time. This is not a career for well-rounded people who like to balance their careers with family and friends.

**heroes/heroines:** Thomas Edison was a boyhood hero — a hard working and unrestrained thinker. Also Werner von Braun, the German rocket scientist who helped start our space program. Currently, I would have to say that I most admire Dr. Sylvia Earle, whose contributions to life cross many disciplines.

**advice:** Deciding you want to be an underwater filmmaker is a little like deciding you want to be a rock star. Many are called, few are chosen. First, learn to be the best diver you can be, completely at home in the water. Second, don't major in film or television in college. Take marine biology or journalism or even business. Learn a lot about a lot of things. Take up still photography and learn all you can on your own. Then buy a movie camera or video camera and go out and shoot. Learn to critique and edit your own work. You will have to make your job because there are few (perhaps no) jobs out there at any given time. Becoming a self-supporting underwater photographer or filmmaker is possible, but difficult. Always have a second career option!

**career opportunities:** Being an underwater filmmaker is different than being an underwater videographer. Filmmakers produce products, a videographer goes out and shoots something. There are no jobs in this world for underwater filmmakers, you work for yourself and sell your shows. However, with more cable channels and more interest in the environment, there are more outlets for your work.

There may be a few jobs for underwater videographers with oil companies or hull inspection services, with tourist operations, or even with research outfits. But not many and they may not be full time.

**10 years:** I hope to be doing exactly what I'm doing now. I hope to be doing it smarter and better. Diving

about his job on p. 28).

Or, if you're torn between your interests in law and the marine field, consider a career in environmental or maritime law, or coastal or ocean policy. As the number of environmental regulations continues to grow, the need for people who understand the science behind the regulations will increase. Science — and an understanding of the way science works — is crucial to determining the success or failure of regulations or policies designed to protect the environment. Education plays a critical role as well, and can serve as the link between the need for such regulations with the outcomes and benefits, or, conversely, the need to update, revise, or do away with regulations that prove ineffective.

Margaret Goud Collins works in policy overseeing the US involvement in an international non-governmental research organization. "As the world becomes more technically oriented and population and development pressures push the limits of the natural order. . . the need and relevance for scientific input is growing," she explains. "The capacity to model natural, social, and economic systems is making predictive capability more useful for policy makers [and] globalization is opening opportunities around the world," she says.

When thinking about careers, work environment is an important factor to consider. Marine-related job opportunities exist in virtually every setting: within government, private industry, academia (schools, colleges, universities), business, and non-profit organizations, to name a few. The positions available may be similar, but the actual day-to-day responsibilities can differ greatly, depending on which avenue you choose. For example, a ship captain could choose to work for the federal government commanding a US Navy ship, for a private oceanographic research institution commanding a research vessel, or for a museum or aquarium commanding a visitors tour boat. While the job title may be similar, the job description could vary greatly.

Another thing to consider is where you'd like to work. Not all marine-related jobs require you to can take a physical toll on a person and my hope would be that no diving accident would prevent me from doing what I love in the future.

## Carmen M. Márquez-Marín — environmental lawyer and marine archaeologist

**B.S., anthropology, Univ. of Puerto Rico**
**M.S., nautical archaeology, Texas A&M Univ.**
**J.D., law, Univ. of Puerto Rico**
**M.S., environmental law, Vermont Law School (candidate)**

**current job:** At present I am specializing in environmental law at Vermont Law School. In the last two years I have been working as a trial lawyer in Legal Services, a nonprofit corporation in San Juan, P.R. I also operate my own business, Archeo Marine Research, where I work as a consultant and researcher in maritime archaeology. My clients are mostly developers and government agencies that must comply with government requirements in order to be able to build structures on the shoreline or in the sea.

**key factor:** The decisive factor was definitely my passion for the sea, which I developed during my early childhood. My curiosity regarding human behavior also influenced my decisions.

**like most:** I like having the opportunity to combine my interest in human behavior and my love of the sea while studying how human beings have interacted with the marine environment at different times in history.

**like least:** This field is relatively new, and it can be frustrating to deal with people who do not understand its importance. Even worse is running into treasure hunters with no respect for history.

**relax:** Mostly, I go to the beach. I love sail sports: windsurfing, sailboating. I enjoy diving and being submerged for long periods of time, but I always follow the recommended decompression guidelines. On land, I enjoy horseback riding, the movies, and the theater.

**heroes/heroines:** I don't have a particular hero, but I admire the Mexican painter Frida Kahlo. Amelia Earhart, and all the other determined, creative, and courageous women who were not afraid to make career choices when there were very few opportunities and lots of restrictions and limitations for them.

**advice:** Persevere and make your dreams come true. Maritime archaeology and environmental law are fabulous disciplines. The work is hard, but the effort is worthwhile. These are the professions of the future.

**career opportunities:** Opportunities in the fields of maritime archaeology and environmental law are definitely on the rise. Environmental lawyers are becoming indispensable to protect natural resources and to establish controls to global commercial development.

**10 years:** I'll probably be working as a lawyer specializing in environmental law. This branch of law includes maritime archaeology and also provides the tools for developing legislation to protect archaeological findings. I hope to continue offering consulting services through Archeo Marine Research. My most precious dream is to create a nonprofit maritime archaeology research institute in Puerto Rico in order to explore and investigate the territorial waters of the island and the Caribbean.

live at the coast, though many opportunities will be near it. Locations around freshwater, such as rivers and lakes, also offer similar career opportunities.

And, don't forget, the best job will be one that combines your interests and skills. Consider what makes you happy. Do you like: working independently or do you prefer being around others? working at your own pace or in a more structured environment? flexible hours or a typical work day with a lunch hour, paid vacations, and sick time? traveling or staying close to home? supervising and leading others or reporting to a supervisor? working in a team setting? being outdoors in all weather conditions, inside at a desk, or a combination?

Having a career that makes you feel good about yourself and your responsibilities is very important. After all, it wouldn't be enjoyable to get up and go to work every day if you didn't like what you were doing. As one marine educator states, "I studied marine biology in college, but I found that my interest did not lie in the hard-core science aspect of this field. I began taking courses in education and I discovered that working with people was of much greater interest to me than working in a laboratory. I investigated museums and aquariums, and found that most of them have education departments that teach about the marine world. This is the perfect setting for me. I have the opportunity to share my delight and interest in marine science with people while at the same time being surrounded by the animals and environment that I have always loved."

Just as learning about the different fields of oceanography is important to scientists and technicians who conduct marine research and strive to understand how the oceans work, learning all you can about the marine environment is important in marine-related careers as well. A career in any aspect of marine science involves a life-long learning process. Because oceanography is a relatively new science, there is a great deal yet to be discovered and understood. What an exciting field to be in! ●

## Kurt Byers — environmental communicator

**B.S., natural resources/environmental communications, Univ. of Michigan, Ann Arbor**

**current job:** As communications manager of the University of Alaska (Fairbanks) Sea Grant College Program, I assess public information needs pertaining to coastal and ocean resources and work with university faculty, my five-member staff of communications professionals, and others to decide what kind of information needs to be provided to our audiences. We produce books, pamphlets, newspaper and magazine articles, fact sheets, web sites, a radio program, exhibits, presentations, and public events, all aimed at sharing knowledge that will promote conservation and wise use of the seas.

**key factor:** In returning to college at age 30 after a decade in private business, I decided I wanted to hone my creative talents — writing, photography, and art — and apply those skills with my business sense in a career that would promote wise stewardship of our natural environment.

**like most:** I get great satisfaction knowing I've found a career that allows me to combine my conservation ethic, empathy for challenges business people face, and creative skills in a way that contributes to maintaining the integrity of our marine environment.

**like least:** The day-to-day demands of managing a communications program prevent me from devoting as much time and effort as I would like to the hands-on creative aspects of communications, such as writing, photography, and graphic design.

**relax:** I'm addicted to music with a special affinity for swinging jump blues. I'm an avid student of ballroom and swing dancing, and like to play golf, shoot hoops, and throw the football. I also like to photograph the many interesting locales I visit. I enjoy carpentry and landscaping, and read a lot — news magazines, newspapers, and novels.

**heroes/heroines:** My only real hero is my father, a steadfast man of great character who, after surviving the perils of World War II as a decorated fighter pilot, teamed with my mother to build the house I grew up in, provide a stable and supportive environment for me and my four sisters, and instill a strong work ethic and social values.

**advice:** Identify your skills and your interests, then search out an educational path that will lead you to a career that taps your unique combination of skills and interests.

**career opportunities:** As long as people are concerned about conserving our marine environment, there will be a need for highly trained and motivated professional environmental communicators who can synthesize, translate, and disseminate important information about marine resources and the effects of human activity on these resources.

**10 years:** I expect I will be a communicator or educator in the field of natural resources, or perhaps teaching others how to become effective communicators.

## Eleanor S. Uhlinger
### — marine information specialist

**B.A., environmental, population, and organismic biology, Univ. of Colorado at Boulder**
**M.L.I.S., Univ. of Washington at Seattle**

**current job:** I am the director of Marine Sciences Information Services at the University of Rhode Island (URI) in Narragansett, R.I. My day-to-day activities focus on the leadership and administration of three University units: the Pell Marine Science Library, the National Sea Grant Depository library, and the Coastal Data and Information Center. Based at URI's Graduate School of Oceanography, my staff and I primarily serve faculty, researchers, and graduate and undergraduate students in the fields of oceanography, marine, and environmental sciences. My three units provide access to the information and data resources our students and scientists need for their research and academic programs. I am also responsible for identifying, managing, planning, implementing, and promoting access to new types of data and information resources and technologies.

**key factor:** My interest in an oceanographic career began when I was 13 years old and attended a weeklong special course at the University of Delaware's marine laboratory in Lewes. Although I did not live close to the ocean, this opportunity and television shows like ***Sea Hunt***, ***Flipper***, and ***Jacques Cousteau*** stimulated my interest in the sea!

**like most:** I love working at the cutting edge of marine science. I feel that librarians play an important role in the scientific process as we help researchers find the information they need to design experiments, compare their results with other datasets, analyze those results, and finally, publish the results for others to review. I also like to work with students or the general public who may be investigating a topic for the first time.

**like least:** As I've moved up the ladder to a more administrative position, I've become more removed from the day-to-day scientific enterprise. Now I spend way too much time in meetings and pushing paperwork. I would prefer to spend more time attending scientific seminars and meeting scientists in their offices and laboratories.

**relax:** Reading, Scottish country dancing, traveling and exploring, helping restore an 18th century farmhouse and grounds.

**heroes/heroines:** Writers! I admire anyone who can successfully put ideas into a cohesive unit — be it a work of fact, fiction, or a scientific treatise.

**advice:** Take as many science, math, grammar/composition, and computer classes as possible. A strong background in a basic science will prepare you well for any career in marine science.

**career opportunities:** Positions in library and information science are definitely increasing. The amount of information being generated is doubling at an alarming rate. Technological advances brought on by the Internet have made it easier to access remote information, but librarians still serve a critical role by organizing and facilitating access to this distributed information.

**10 years:** Good question! I hope to be moving into a new library building that I'll be planning and building in the years ahead. The new library will include spaces for people, information in all its shapes and forms, and whatever technology we're using in the decades ahead.

## Stuart E. May
### — aquarium curator

**B.A., environmental studies, Gettysburg College**

**current job:** I am the husbandry curator at the North Carolina Aquarium at Pine Knoll Shores. I supervise the husbandry staff, including aquarists who maintain the aquatic exhibits, a lab tech who monitors water chemistry, and several summer interns. We are responsible for all aspects of animal care. We build some of the aquariums, construct the life support systems, collect the animals, feed them, and take care of them.

A part of my duties includes assisting with the marine mammal and sea turtle stranding networks. The aquarium is available to help transport and rehabilitate injured mammals and turtles.

**key factor:** An aquarium is a very stimulating place. I enjoy working with the animals as well as with the mechanical systems.

**like most:** I enjoy designing and building new aquarium systems. The technology has advanced dramatically over the past 20 years and it is a challenge to incorporate the new technology into an old facility.

**like least:** Working with the state bureaucracy.

**relax:** I play soccer and racquetball. I coach my daughters' soccer teams. I enjoy camping and recreational scuba diving. I also enjoy astronomy and stargazing as well as watching and playing Jeopardy.

**heroes/heroines:** My parents, Audrey and Semuel May, who kept me on the straight and narrow. Austin Williams, my fifth grade teacher, who introduced me to science. Robert Barnes, a college professor who taught about invertebrates. Rosa Parks, who stood up to be counted.

**advice:** Try to get as much job training as possible. Aquariums need experienced employees. Most of the detailed aquarium knowledge is learned on the job.

**career opportunities:** New aquariums are opening all over the country.

**10 years:** I hope to be director of operations and husbandry here at the North Carolina Aquarium.

## Faith A. McGruther
### — resource manager

**current job:** I am the executive director of the Chippewa/Ottawa Treaty Fishery Management Authority (COTFMA), an organization responsible for managing, enhancing, and regulating the natural resources of the portions of the Great Lakes covered by the Treaty of 1836. Under the terms of the treaty, the tribes harvest whitefish and lake trout as well as some chubs, salmon, and walleye. At the present time, four tribes are members of COFTMA: the Bay Mills Indian Community, the Sault Ste. Marie Tribe of Chippewa Indians, the Grand Traverse Band of Ottawa and Chippewa Indians, and the Little River Band of Ottawa Indians.

**key factor:** There was never a defined "career decision" per se as my career went forward. The more I learned about treaty fishing, the more intrigued I became with what was happening in the fishery. It is the type of work that is always challenging and never boring. Also, I love the Great Lakes, their beauty, and all natural resources on Mother Earth.

**like most:** I have really enjoyed meeting lots of new and interesting people.

Some of them — Helen Hornbeck Tanner, Senator John Glenn, Senator Daniel Inouye — have really impressed me. I have also made some marvelous friends through the years.

I also would like to believe that what I am doing is making a difference in the Great Lakes in helping to make sure there is a fishery for future generations. Fishing has been a part of our way of life from the beginning and should be able to go on as part of our heritage.

**like least:** Traveling. I hate to fly.

**relax:** I love to spend time with my grandchildren. Also, I like to garden. I get so engrossed in what I am doing that I don't think about all the things I was stressed about.

**heroes/heroines:** One of my heroes is John F. Kennedy. I think he really tried to do what was best for this country. Another is my sister, who has always been there for me and supported me no matter what I did.

**advice:** The best thing any high school student could do today, no matter what field they are going into, is to go to college and get a degree. I regret not doing so most of all. Learn how to be comfortable speaking in front of people and meeting new people.

**career opportunities:** I believe that, more and more, women are becoming important in every field. I believe jobs within the natural resource field will increase even though right now, with the budget crunches, it is pretty level.

**10 years:** I will be retired and volunteering my time on tribal committees. That way I will still be involved in some way with the natural resources of my tribe.

## Myron J. Kebus
### — aquaculture veterinarian

**B.S., biology, Michigan State Univ.**
**M.S., aquaculture, Univ. of Wisconsin at Madison**
**D.V.M., veterinary medicine, Univ. of Wisconsin at Madison**

**current job:** I am the state aquaculture veterinarian for Wisconsin. I work closely with fish farmers to address issues of fish health. Roughly, I spend equal portions of time in the office, in the field, at meetings, and in the laboratory.

*(continued on page 32)*

# Career Outlook

As you have seen in this guide, the marine sciences offer many educational and employment opportunities. But what are the chances of finding a job in your field of choice?

Your ability to land a job in the marine sciences will depend on many factors. And, while some of those factors will be out of your control, it's important to prepare yourself as best you can. Throughout this publication, a few key messages were repeated by several of the people featured. Their advice (see page 30) is based on experience, so you may want to heed their advice as you make important educational and career decisions.

## Research Careers

Students interested in pursuing a research career may find opportunities in academia, industry, government, non-profit and non-governmental organizations, consulting firms, and owning their own businesses. Many factors influence job opportunities in these areas, including the economy, funding, and distribution of government support.

### *Researchers in Academia*

Within an academic setting, there are basically three possibilities for employment: research and training, teaching and research, and teaching and modest research. Most positions require at least a master's degree, and preference is generally given to those holding a Ph.D.

While a research career at a university (consisting of research and training) was once considered the "traditional" career path for Ph.D. graduates in the marine sciences, changes in the academic world coupled with funding uncertainties have made this path far less predictable. An increasing number of Ph.D. graduates are working in colleges where teaching is the focus of the position and research is secondary or minimal. Such settings include four-year colleges, junior colleges, and community colleges.

A study commissioned by the National Academy of Sciences (NAS), found that Ph.D. graduates are finding non-academic jobs more easily than academic research positions. According to the study, that includes jobs in nontraditional occupations — patent law, science policy and administration, the media, investment firms, and novel educational settings. Also noted: a growth of employment in medical research industries including biotechnology, research supplies, and pharmaceutical companies.

While academia is still the largest employer for Ph.D. recipients, statistics may be misleading. The NAS study identified a recent trend that may be boosting employment figures for graduates: the "postdoc" or postdoctural position.

Traditionally, a postdoc is the first job taken by a Ph.D. graduate in a research or academic institution. Some graduates find that they have to take back-to-back postdoc positions to stay employed. And postdocs, once seen as a fall-back job, are getting harder to come by.

That has been Laura Magde's experience. Magde, a marine geophysicist who earned her Ph.D. in 1997, discovered that pursuing a career in the academic research setting is so difficult she may be forced out of the field. After her postdoc position ran out, she interviewed for several jobs, including additional postdoc opportunities, to no avail. "There are simply way too many people for far too few jobs," she states.

Dr. Susan M. Henrichs, professor of marine science and department head at the University of Alaska's School of Fisheries and Ocean Sciences in Fairbanks, has spent her entire career in research and teaching in academia. She believes that the outlook for a career like hers "will remain about the same." Her forecast is based on the status of research funding. "Because the trend is to stagnate state and federal funding of both research and higher education," she explains, "growth of my field seems unlikely." Her advice to students: "get some research experience as an undergraduate; find out if you actually like research before you commit to graduate school."

So what can students interested in pursuing a career in the ocean sciences expect? According to the experiences of graduate school alumni from Consortium for Oceanographic Research and Education (CORE) institutions, obtained through a 1995 survey, the following:

- Graduates will hold a number of jobs in a variety of sectors.
- Most graduates can expect to change jobs often.
- Many funding mechanisms, such as internships, externships, traineeships, teaching assistantships, and research assistantships, provide the vehicles for educational experiences that are useful in postgraduate careers.

### *Researchers in Industry*

Research careers in industry are very diverse, and "industry" is difficult to characterize. Nicholas Basta, in his 1992 book ***Environmental Jobs for Scientists and Engineers***, writes, "in the overall job market, there has been a trend among Ph.D. scientists and engineers toward working in industry and a corresponding decline to their working in academia. . . The grand summation of these trends is that the scientific enterprise is becoming increasingly interwoven with the economic enterprises of the United States."

Dr. Jay W. Gooch is an environmental scientist with Procter and Gamble. In his position, Gooch helps provide the company with the tools and expertise necessary to ensure that its products are safe. "While some people find careers in industry that are hard to distinguish from an academic career — that is, mostly research — others find a blend of research and product-oriented problem-

solving and management," he says.

Numerous opportunities for research careers in industry exist within environmental departments and R&D divisions of large corporations. Within industries such as pharmaceuticals, biotechnology, construction, manufacturing, energy production, and resource exploration and development, scientists and engineers provide important data to company managers. This research can be used to create new products, improve existing products, or discontinue ineffective products.

As a rule, industry tends to be dependent on external factors such as the economy and consumer-driven market demand. Other characteristics of industry research careers are regular hours and the importance of teamwork.

Because teamwork is important, communication skills and the ability to relate to and interact with peers are highly valued by employers. "Unlike many independent academic researchers, successful industry scientists have a strong focus on 'what's best for the company,'" said Gooch.

Other opportunities exist in nontraditional private industry, outside the realm of R&D. Insurance companies rely on oceanographers to predict and understand weather-related hazards and natural disasters. Transportation-related industries, such as airlines and shipping companies, also rely on advances in oceanography and engineering — weather forecasting and navigation technologies, for example — to run their businesses efficiently and safely.

Human health-related industry is another large employer of scientists and technicians. Bruce Altrock, an independent consultant and former vice president of research at a large biotechnology company, predicts strong growth in research that relates to new therapeutics. "[N]ew information and technology coming out of current research sets the stage for the development of novel therapeutics to address a variety of human diseases," he explains. "Interestingly enough, many leads in the search for these novel compounds will undoubtedly come from marine sources as they have in the past."

### Advice from the Experts

- Take as many math and science courses as you can, starting in high school and continuing throughout your undergraduate years. This is important for students interested in research and non-research careers because the math and sciences provide a solid base of knowledge about the way things work and how to solve problems. Computer and writing skills are important too.
- Do not specialize too early! Keep your options open. Even if you think you want to pursue a postgraduate degree, hold off on selecting a specialty area as an undergraduate. This could limit your options later.
- Be flexible! One course, professor, book, experience, or adventure could open your eyes to a career you might never have considered. Remember: very few people currently employed in oceanography or the marine sciences get to their positions by taking the same path.
- Be persistent! Worry less about job forecasts and more about working at what you really want to do in life. With hard work, enthusiasm, and creativity, you can achieve your goals.
- Volunteer, volunteer, volunteer! Start young and never pass up an opportunity to get experience in an area that interests you. Volunteer opportunities, internships (paid and unpaid), fellowships, camps, mentoring programs, science clubs, and independent research projects will give you a taste of what the field is like and may give you an edge over someone who lacks experience.

*Researchers in Government*

As with research jobs in industry, those in government are difficult to generalize. Jobs for scientists and engineers exist in government research labs or departments and in areas such as policy and management. These jobs exist at the federal, state, and local levels. With the current push to downsize the federal government, many believe opportunities at the city, local, and state government levels will increase, while federal opportunities will decrease.

Being a government scientist differs from being a scientist employed by a university or private research facility. Dr. Kathryn Sullivan, former chief scientist at the National Oceanic and Atmospheric Administration (NOAA), once described the difference as a trade-off.

"Government scientists," she said, "perform research that is relevant to the missions of their agencies. While this research may still be in areas of fundamental science, the agency must be able to envision an eventual societal benefit and may sometimes require the individual to direct his or her inquiries in a certain field. In return for this, government scientists are granted certain freedoms, most notably a certainty that they will indeed be employed in research."

Dr. Steve McCormick, a research physiologist with the National Biological Service of the US Department of the Interior, agrees. "Certainly, a characteristic that differentiates government research jobs from jobs in academia is not always needing to write grants to secure funding. But, on the down side, you don't have the freedom to pursue your real research interests because you're often constrained by the agency needs."

McCormick adds that the emphases of government agencies change as the government responds to changing research needs. He cites the NIH as a symbol of success in government-sponsored research. "The core mission of NIH has remained the same over the years, but individual focus areas and priorities change all of the time. This is necessary and important."

In addition to his government position, McCormick has an affiliation with a university, a

combination he considers a real benefit. Such an affiliation, which can involve teaching and advising students, is generally feasible for government researchers and is fairly common.

Dr. Alexander Shor is a program director in the National Science Foundation's (NSF) Ocean Sciences Division, where he manages funds that will be distributed through NSF's research grant programs. Because federal government is in a down-sizing trend, Shor doesn't see career growth in his field, though he does see increasing opportunities for scientists to serve in temporary positions, something he recommends. If working at a federal research agency is something that interests you, Shor suggests getting research and/or teaching experience in that specialty before planning to shift into the funding realm.

### *Researchers in Non-profit and Non-governmental Organizations*

Non-profit and non-governmental organizations provide additional career options for scientists and engineers, in addition to the many opportunities they offer non-researchers.

Some of these groups are similar to academia in their research-based missions [for example, the Woods Hole Oceanographic Institution (WHOI), the largest independent oceanographic institution in the world, is a private, non-profit research facility, and the Monterey Bay Aquarium Research Institute is a part-science, part-engineering institute that develops instruments, systems, and methods for scientific studies of the deep ocean and specializes in exploration with remotely operated vehicles]. Other non-profit organizations concentrate more on environmental advocacy (well-known examples include the Nature Conservancy, the World Wildlife Foundation, Greenpeace, and the Sierra Club).

A non-governmental organization (NGO) is generally defined as a nonprofit group or association organized outside of institutionalized political structures. Many NGOs have social objectives, while others serve particular constituencies. NGO activities range from research, information distribution, training, local organization, and community service to legal advocacy, lobbying for legislative change, and civil disobedience. NGOs range in size from small community groups to huge organizations with national or international memberships.

Because there are so many non-profit and non-governmental organizations, there are many choices in terms of specialty area, size, and geographic location. A concern for many in these sectors is funding pressure and competition, the relatively small number of pure research positions available, and the salaries, which tend to be lower than in industry or academia.

### *Researchers in Consulting Firms or Private Enterprise*

Environmental consulting is another career option for research scientists. Consulting companies range in size and scope from large, international, multi-specialty firms to small companies specializing in one field. Consulting careers have offered researchers many opportunities in the past. Whether or not this trend will continue is hard to predict. The field is highly competitive and, as such, often requires competent presentation skills. Keep in mind that most consultants have prior experience in some aspect of research or teaching before venturing out on their own or joining a consulting firm.

An increasingly attractive option for many scientists and engineers is starting a business. This allows for flexibility and may be a way to combine a part-time teaching position with independent research and "research for hire." On the down-side, one should be willing to put in long hours and a fair amount of unpaid work in order to get established.

### *Summary*

In addition to being good scientists and engineers, today's researchers must also be good writers and speakers. Not only do researchers need to submit proposals to funding sources in an attempt to get financial support for their research, they must also present their results to colleagues, decision-makers, students, and funding sources. As Gregory Johnson, a NOAA oceanographer with the Pacific Marine Environmental Laboratory states, "Science does no good unless it is communicated to others."

### Non-Research Careers

A research career is certainly not the only option for students interested in the exciting field of marine science. In fact, the possibilities for a non-research career are as varied as one's desires and imagination.

Changes in the economy and politics can impact non-research marine careers in much the same way they impact the research community. A common example is federal support for education, which, in times of budget cuts, generally translates to cuts at the state and local levels. Eventually, federal budget cuts reach the small, community-based programs such as after-school science clubs, science museums, and nature facilities as well as educational programming on science or the environment.

With projections for the US labor market favoring the information, service, and technology sectors, what will this mean for students interested in a marine-related career? For one thing, more opportunities in the information and mass communication sectors seem likely, as do opportunities in marine industries, such as marine electronics, aquaculture, environmentally based recreation and tourism, engineering, hydrogeology, water quality management, and environmental education and communication.

According to Dr. Judith McDowell, senior scientist and associate dean of the education program at WHOI, the overall outlook for a career in the marine sciences is bright. "New jobs in marine sciences are expanding in many sectors due to continuing advances in technology and a growing appreciation for the importance of the oceans to all life on earth," she says. "The next decade should bring an even greater array of challenges and careers than we see at present. The future is exciting."●

## **Toba/**marine biology

also frustrating to work with a bureaucratic type of government. Although smaller than the state or federal government, tribal governments have the same politics.

**relax:** I like to work in my yard and garden. With more and more of my work being spent in the office, spending any time outdoors is very relaxing.

**heroes/heroines:** I am of Japanese descent and have the utmost respect and admiration for not only my great-grandparents and grandparents, but also for all of the first-generation pioneers who left their homeland for a new life in the US. They sacrificed much and faced much hardship and discrimination. Their efforts paved the way for my generation.

**advice:** Take a variety of classes to get a well-rounded education. While science and math classes are important, so are writing, public speaking, social sciences, and the other classes that may not seem that important to you. Try hard in all your classes, even the ones you may not particularly like.

**career opportunities:** Career opportunities in fisheries are generally increasing. With increasing public awareness of environmental concerns, the Endangered Species Act, and water concerns, there are more jobs now than there were 15 years ago. I have a background in aquaculture and the number of jobs in aquaculture is increasing. Production of aquaculture products in the western US has been gradually increasing over the past 10 years. As new products are raised and production is increased, the related opportunities in technical organizations, academic institutions, and private companies will also increase.

**10 years:** I would like to continue to work for the Tulalip Tribes in developing the shellfish program. However, the primary goal of the tribe is to provide educational opportunities to tribal members to fill positions within tribal management.

## **Hall/**oceanography

**relax:** I like to exercise, especially lifting weights. I like to go on long walks with friends and family. And I like to read. But mostly, I enjoy being in the company of people I love, especially my wife, Carol.

**heroes/heroines:** My main hero is my father. He is an African American who went on to be a scientist at a time when that was a difficult thing to do. He never attained his doctoral degree, but he instilled in me a desire to learn and to question.

**advice:** Never be afraid to ask questions, never be afraid to learn, and read, read, read. There are many opportunities opening up for young people in marine science. Find out about them, and don't be afraid. We are here to help you.

**career opportunities:** There are presently not many openings in academia. However, within industry, the job market has improved. The petroleum industry has been hiring more young people with degrees in marine science, as have environmental and engineering firms.

**10 years:** I hope to be working closely with teachers. I hope to be an educator until I retire.

## **Buck/**ocean engineering

**career opportunities:** I think marine mammal science is demonstrating a slow increase in career opportunities. People are realizing all the time that we still have a lot to learn about these animals and how they live and communicate in the ocean. In the last five years I have seen a modest increase in funding for research activities in this area.

**10 years:** I think I will still be working both in signal processing and acoustics research, and teaching both undergraduates and graduates. One long term goal I have is to write a book on signal processing and marine mammal communications, but I think there are still a lot of things I need to learn before I write that book.

## **Kebus/**related fields

**key factor:** I have always enjoyed fish. I was determined to be a veterinarian. Becoming a fish veterinarian combined the two and has been an interesting journey.

**like most:** Working with fish farmers. They want to do a good job, they enjoy working with fish, and they like to have fun.

**like least:** Veterinary professionals struggle to be adequately compensated. This is an important consideration for anyone thinking of pursuing a career in veterinary medicine at this time.

**relax:** Raise koi and goldfish at home. Garden, read newspapers from anywhere and everywhere, and take long hikes.

**heroes/heroines:** My family and friends, and people in everyday life who demonstrate the courage to do what is right because it is right and not because they want to be seen as heroes.

**advice:** Listen to your heart, work very hard, and don't allow people to discourage you. Don't narrow your focus. You need a variety of skills — language, math, and economics as well as biology — to be an effective veterinarian. Learn by doing.

**career opportunities:** The opportunities are increasing for a limited number of properly trained veterinarians. This is very much a career in which you create opportunities for yourself and others.

**10 years:** Several years ago I would not have guessed I would be doing what I am doing now. Ten years from now I will be involved with aspects of aquaculture that I am not even thinking about now.

# Sea Grant Programs

**National Sea Grant College Program**
National Oceanic and Atmospheric Administration
SSMC3 Room 11736
1315 East-West Highway
Silver Spring, MD 20910
301/713-2431

### ALASKA
Alaska Sea Grant
Univ. of Alaska
P.O. Box 755040
Fairbanks, AK 99775-5040
907/474-7086

### CALIFORNIA
California Sea Grant
Univ. of California-San Diego
9500 Gilman Dr.
La Jolla, CA 92093-0232
858/534-4446

USC Sea Grant
Wrigley Institute for Environmental Studies
University Park
Los Angeles, CA 90089-0373
213/740-1961

### CONNECTICUT
Connecticut Sea Grant
Univ. of Connecticut
1084 Shennecossett Rd.
Groton, CT 06340
860/405-9127

### DELAWARE
Delaware Sea Grant
Univ. of Delaware
Robinson Hall, Rm. 111
Newark, DE 19716
302/831-2841

### FLORIDA
Florida Sea Grant
Univ. of Florida
Box 110400
Gainesville, FL 32611
352/392-5870

### GEORGIA
Georgia Sea Grant
Univ. of Georgia
Marine Sciences Bldg.
Athens, GA 30602-3636
706/542-6009

### HAWAII
Hawaii Sea Grant
Univ. of Hawaii
2525 Correa Rd., HIG 238
Honolulu, HI 96822
808/956-7031

### ILLINOIS
Illinois-Indiana Sea Grant
Univ. of Illinois
63 Mumford Hall
1301 W. Gregory Dr.
Urbana, IL 61801
217/333-9448

### INDIANA
Illinois-Indiana Sea Grant
Purdue Univ.
Dept. of Forestry and Natural Resources
1200 Forest Products Bldg.
W. Lafayette, IN 47907-1200
765/494-3573

### LOUISIANA
Louisiana Sea Grant
Louisiana State Univ.
Sea Grant Bldg.
Baton Rouge, LA 70803-7507
225/388-6448

### MAINE
Maine Sea Grant
Univ. of Maine
5715 Coburn Hall
Orono, ME 04469-5715
207/581-1435

### MARYLAND
Maryland Sea Grant
Univ. of Maryland
0112 Skinner Hall
College Park, MD 20742
301/405-6371

### MASSACHUSETTS
MIT Sea Grant
Massachusetts Institute of Technology
Bldg. E38, Rm. 300
77 Massachusetts Ave.
Cambridge, MA 02139
617/253-7041

WHOI Sea Grant
Woods Hole Oceanographic Institution
193 Oyster Pond Rd.
CRL 209
Woods Hole, MA 02543-1525
508/289-2665

### MICHIGAN
Michigan Sea Grant
Univ. of Michigan
2200 Bonisteel Blvd.
Ann Arbor, MI 48109-2099
734/764-1118

### MINNESOTA
Minnesota Sea Grant
Univ. of Minnesota, Duluth
2305 E. 5th St.
Duluth, MN 55812
218/726-8106

### MISSISSIPPI
Mississippi-Alabama Sea Grant Consortium
703 East Beach Dr.
P.O. Box 7000
Ocean Springs, MS 39566-7000
228/875-9341

### NEW HAMPSHIRE
New Hampshire Sea Grant
Univ. of New Hampshire
Kingman Farm
Durham, NH 03824-3512
603/749-1565

### NEW JERSEY
New Jersey Sea Grant
NJ Marine Sciences Consortium
Bldg. No. 22
Ft. Hancock, NJ 07732
732/872-1300

### NEW YORK
New York Sea Grant Institute
SUNY at Stony Brook
121 Discovery Hall
Stony Brook, NY 11794-5001
631/632-6905

### NORTH CAROLINA
North Carolina Sea Grant
North Carolina State Univ.
Box 8605
Raleigh, NC 27695-8605
919/515-2454

### OHIO
Ohio Sea Grant
Ohio State Univ.
1541 Research Center
1314 Kinnear Rd.
Columbus, OH 43212
614/292-8949

### OREGON
Oregon Sea Grant
Oregon State Univ.
402 Kerr Admin. Bldg.
Corvallis, OR 97331-2131
541/737-2716

### PUERTO RICO
Puerto Rico Sea Grant
Univ. of Puerto Rico
P.O. Box 5000
Mayagüez, PR 00681-5000
787/834-4726

### RHODE ISLAND
Rhode Island Sea Grant
Univ. of Rhode Island
Narragansett Bay Campus
Narragansett, RI 02882-1197
401/874-6842

### SOUTH CAROLINA
South Carolina Sea Grant Consortium
287 Meeting St.
Charleston, SC 29401
843/727-2078

### TEXAS
Texas Sea Grant
Texas A&M Univ.
1716 Briarcrest Dr., Suite 603
Bryan, TX 77802
979/862-3767

### VIRGINIA
Virginia Sea Grant
Virginia Graduate Marine Science Consortium
Madison House
170 Rugby Rd.
Charlottesville, VA 22903
804/924-5965

### WASHINGTON
Washington Sea Grant
Univ. of Washington
3716 Brooklyn Ave., N.E.
Seattle, WA 98105-6716
206/543-6600

### WISCONSIN
Wisconsin Sea Grant
Univ. of Wisconsin-Madison
Goodnight Hall, 2nd floor
1975 Willow Dr.
Madison, WI 53706-1177
608/262-0905


NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE
Sea Grant
National Sea Grant College Program

ECOHAB (short for ecology of harmful algal blooms). The Gulf of Maine portion of the ECOHAB project is seeking to determine the source and distribution of *Alexandrium* cells (*Alexandrium* is the organism that causes paralytic shellfish poisoning, PSP, and is considered one of several harmful algal blooms, once referred to as "red tide."), and the role of ocean currents and plumes in transporting the cells to nearshore areas where they "bloom" and become toxic, poisoning shellfish. The role of physical oceanographers is to assist with oceanographic and satellite measurements, computer modeling, and instrument design, deployment, and recovery. The collaboration continues, with the ultimate goal of, one day, being able to predict toxic bloom events.

### Chemical Oceanography

The ocean has been referred to as a "chemical soup" because it contains many chemical compounds, elements, gases, minerals, and organic and particulate matter. While water is the most plentiful ingredient, salts are among the most important. Amazingly, despite the major changes that have taken place on Earth throughout history — continental collisions, land formations, glaciation — the basic composition of seawater has remained relatively constant for millions of years.

Chemical oceanographers, also called marine chemists, marine geochemists, or even marine biogeochemists, may study one or a combination of the following: formation of seawater and seafloor sediments, relationships between chemical compounds (both organic and inorganic), how chemical inputs to the ocean (including pollution) affect it, and how the chemistry of the ocean affects or is affected by biological, geological, and physical factors. As with the other disciplines of oceanography, chemical oceanographers rely on and interact with researchers from the other disciplines.

One important aspect of chemical oceanography is the study of pollutants. This work may lead chemical oceanographers to the deep ocean, coastal bays and estuaries, or inland rivers, streams, and lakes. Sources of pollutants range from the obvious (sewage, oil or fuels, ocean dumping) to sources that are harder to detect or trace (agricultural or lawn runoff containing chemical fertilizers, leaking septic systems, road runoff, or storm drain overflows). Chemical oceanographers study the impact of such pollutants by examining how they interact with seawater, marine life, and sediments. Chemicals and pollutants introduced to a marine environment may behave very differently depending on environmental conditions such as salinity, wind, rainfall, temperature, and transport methods. Transport methods include land-based (for example, surface runoff or groundwater), water-based (rivers and streams), and atmosphere-based (rain and dust).

The study of carbon and its role in global climate change has captured the attention of chemical oceanographers for decades. Since the industrialization of the 18th century, researchers estimate that the amount of carbon dioxide in the atmosphere has increased by 25 percent. Although the scientific debate continues over whether the increase in atmospheric carbon dioxide has caused global warming or vice versa, it is generally accepted that modern society has added to the amount of carbon dioxide in the atmosphere.

What does all this mean? Since carbon dioxide absorbs infrared radiation (heat), an increase in carbon dioxide in the atmosphere would keep the heat from escaping into space. This would cause the Earth to warm up just as a greenhouse holds heat, thus the popular term "greenhouse effect." Chemical oceanographers are working to understand the ocean's role in this and other theories related to global climate change.

Modern society's rapid technological advances, including the development of complex chemical compounds and processes used to produce and manufacture energy, food, clothing, medicine, and other products, have created a need for chemical oceanographers. In the quest for bigger, stronger, faster, more, the costs of "improvements" often get overlooked. For example, the disposal of waste that results from products and by-products can be a problem in itself. Who would have thought that household cleaning products, fertilizers, pesticides, boat paints, and leaded fuel — all products that saved time, worked better, and often cost less — could have contributed to the degradation of many marine and coastal areas? Fortunately, researchers in many oceanographic disciplines and related areas, including marine chemists, have worked together to improve our understanding of such impacts, which has, in turn, led to improved controls, regulations, testing methods, and ultimately, safer products.

The work of chemical oceanographers will continue to provide answers to important questions. For example, the use of the oceans for waste disposal and as a source for drugs and minerals will require cooperative research between ocean chemists, biologists, and geologists. It is the work of marine chemists that aids ocean engineers in the development of instruments, vessels, and ocean vehicles that, in turn, improve the ability of researchers of all oceanographic disciplines to go to sea, collect data, and discover previously unknown formations, marine life, and phenomena.

As the population discovers new ways to use the oceans — be it for food, transportation, energy, or waste disposal — chemical oceanographers will play an important role in improving our knowledge about the impact of these activities on the ocean and its ability to sustain them. ●

# Ocean Engineering

**The field of ocean engineering** provides an important link between the other oceanographic disciplines such as marine biology, chemical and physical oceanography, and marine geology and geophysics. Just as the interests of oceanographers have driven the demand for the design skills and technical expertise of ocean engineers, the innovations in instrumentation and equipment design made by ocean engineers have revolutionized the field of oceanography. This is especially true within the last three decades.

The invention of thousands of oceanographic instruments and devices has changed the way oceanographers study the oceans and coasts. Examples include: computer- and satellite-linked buoys and floats, sediment traps, ocean seismometers (instruments that measure seafloor movement in a manner similar to the way seismographs measure earthquake activity on land), underwater video equipment, acoustic measuring devices (instruments that make it possible to "sense" underwater objects and seafloor formations), and underwater vehicles, including submersibles and remotely operated vehicles (ROVs). Information that once took years to compile, and that frequently involved sampling in harsh weather conditions, can now be accomplished in minutes, often from remote locations, including ships and laboratories. The innovations of ocean engineers have enabled oceanographers to travel farther offshore and deeper into the sea, and to stay there for longer periods of time. Because of ocean engineers, major oceanographic discoveries — including hydrothermal vents, ocean volcanoes, thousands of miles of underwater mountain chains, "new" species, and biological, chemical, geographical, and physical processes and phenomena — have been made.

Ocean engineering is actually a combination of several types of engineering: a mix of mechanical, electrical, civil, acoustical, and chemical engineering techniques and skills, coupled with a basic understanding of how the oceans work. The importance of working in partnerships with oceanographers from other disciplines is critical, as the challenge of working in the ocean environ-

## Langley R. Gace
### — ocean engineer

**B.S., physics, Bates College**
**M.S., ocean engineering, Univ. of New Hampshire**

**current job:** I am an ocean engineer at Ocean Spar Technologies on Bainbridge Island, Wash. Our company develops and sells high performance offshore aquaculture cages to customers worldwide. Most of my time is spent developing computer models of cages and learning how they will behave in the offshore environment. I also spend some of my time out at sea inspecting our products after they have been installed and visiting potential sites for raising fish with customers.

**key factor:** The ocean has always fascinated me. Ocean engineering seemed like the perfect way to combine my love of the sea and my physics degree from college. Also, my great uncle Athelston Spilhaus, who helped start Sea Grant, was an ocean engineer. While growing up I would hear about the marvelous projects he was working on, so it seemed quite natural for me to head in this direction.

**like most:** The fact that we are producing a product that ultimately provides food to the masses and doing it in an environmentally conscientious fashion.

**like least:** The industry's lack of vision sometimes frustrates me. Fish farmers are very wary when it comes to trying new ideas.

**relax:** I love to go sailing. I also enjoy golf and working around the house and garden with my wife.

**heroes/heroines:** I have two heroes. One I have mentioned: Dr. Athelston Spilhaus. His creativity was simply amazing. My other hero is anyone who goes out and makes the very best of each day despite circumstances.

**advice:** Don't go directly into ocean engineering. Get a mechanical or civil engineering degree first. It is there that you learn the basics. Though I was a physics major, I took the basic engineering courses before I went to grad school and that made all the difference.

**career opportunities:** The job potential in aquaculture is strong for engineers. As the demand for offshore rather than nearshore cages has increased, so has the need for talented engineers to build structures that will survive out there.

**10 years:** I would still like to be involved in offshore aquaculture in some capacity. I hope that the industry will have matured some by then so that there will be different challenges.