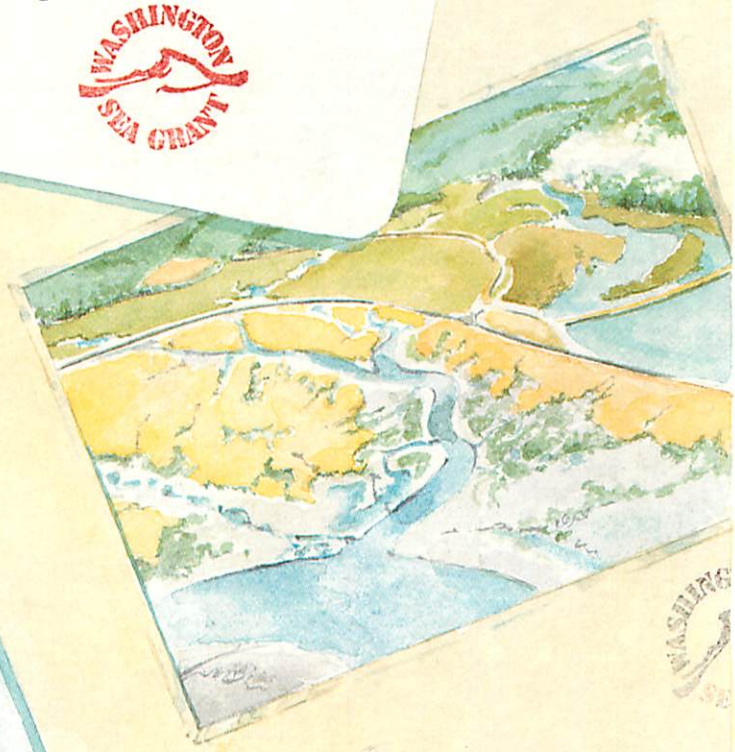
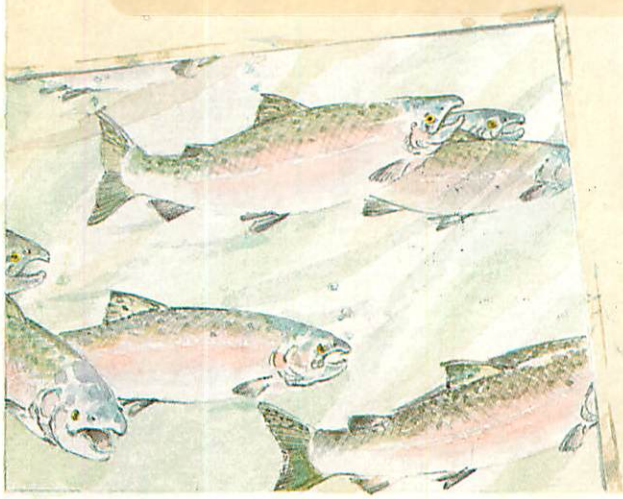
Biennial Report
1983 - 1984





The Washington Sea Grant Program was created in 1968 as part of a national network to promote the understanding, wise use and enhancement of state, regional and national marine resources through a broad integrated program of research, education and public service. The program, based in the University of Washington, also includes a range of other educational institutions, working in partnership with industry, government and the public.

Research

Research, including graduate student thesis and dissertation activity, is the largest component of the program, accounting for over 50% of program expenditures. In 1983-1984, research involved 45 faculty members and 50 students in four different institutions. The goal of each project is threefold: new and useful knowledge about the marine resources, the publication of that knowledge, and the training of graduate students who will become the scientists, businessmen, and managers of the future.

Education

Though the smallest percentage of program funds was devoted in 1983-1984 to discrete formal education projects, this program function is far reaching in addressing the Congressional mandate "to develop the skilled manpower, including scientists, engineers, and technicians... necessary for the exploitation of these (marine) resources." The education function not only includes formal projects but is embedded in research and advisory services.

Education projects take various forms. At the University of Washington, seed money stimulates the development of new curricula and supports lectures by eminent scientists and scholars. Internships provide selected students opportunities for one-year assignments to Congressional committees and federal agencies. Off-campus, the needs of K-12 classrooms are addressed by the development of specialized marine curricula and programs. In the past, sweeping vocational and college curricula supported by Sea Grant have transformed marine education in the state of Washington.

Education is also heavily supported through the students involved in research projects and through the substantial public education activities of the Advisory Service program.

Public Service

The public service function permeates all program activities. It is formalized in the Advisory Service and Communications programs, which together account for one-third of the program budget.

Advisory Services provides an essential link between the marine community and the university. Specialists and agents who comprise this segment of the program identify and report the community's needs for research. In turn, they disseminate research results to resource users and managers.

In Washington, the program develops educational programs, technical information, and publications useful to private and public resource users and managers in seven constituent sectors:

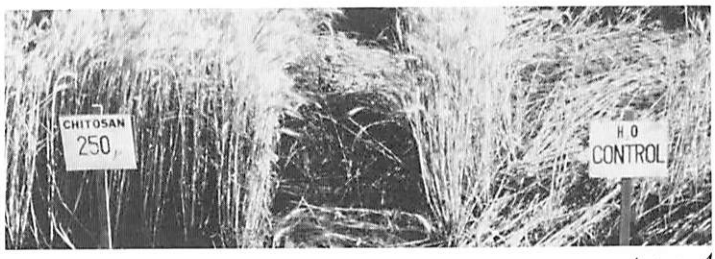
- Aquaculture
- Commercial fishing
- Seafood processing and marketing
- Marine manufacturing, trade and services
- Marine recreation and the tourism industry
- Ports, harbors, and marine transportation
- Government agencies and other public institutions

Field advisory offices are located at Seattle's Fishermen's Terminal and in Bellingham, Montesano and Vancouver. These offices are run in cooperation with Seattle Central Community College, Bellingham Vo-Tech Institute, and Washington State University/Cooperative Extension. Specialists are based at the University of Washington and work cooperatively with the faculties of the Institute for Marine Studies, the Institute for Food Science and Technology, and the Schools of Fisheries and Oceanography.

A communications office makes the results of the other program elements available to a broad array of the marine community. In addition, a strong tradition of book publishing has made Washington Sea Grant books a staple on marine-oriented bookshelves throughout the world.

Rapid Response/Program Development

A small body of funds is used to respond to special needs and oportunities as they arise and to provide seed money for future endeavors. In 1983-1984, among other things these funds made possible a badly needed study on critical Puget Sound habitats, a major international symposium on salmon, several conferences for the general public on emerging marine issues, and startup funds that led to several of the projects reported in this document.



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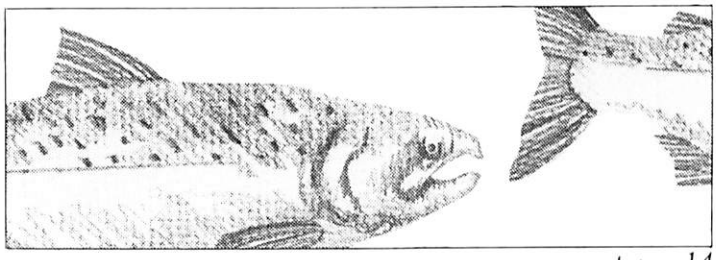

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DEPARTMENTS

Program Management, 1983-84

Director
Louie S. Echols

Assistant Director for New Programs
Alyn C. Duxbury

Assistant Director for
Marine Advisory Services
Robert E. Harris

Communications Manager
Patricia Peyton

Administrative Services Manager
C. Alan Krekel

Washington Sea Grant Program
3716 Brooklyn Avenue N.E.
Seattle, WA 98105
Telephone: (206) 543-6600

This report has been prepared to comply with requirements of grant number NA84AA-D-00011 from the National Oceanic and Atmospheric Administration to the Washington Sea Grant Program. Funds to support publication of this report have been provided by the University of Washington.

Editor, Patricia Peyton; *Writer,* Sally Lawrence;
Graphics, Vicki Miles *Cover illustration:* Rick Koppes

From the DIRECTOR

In this report, we describe some major achievements of the Washington Sea Grant Program during 1983 and 1984. We have not attempted to cover every program activity. Rather, we have highlighted for the interested and concerned public particularly promising developments in our continuing effort to assist the utilization, enhancement and preservation of the marine resources of this state, region and nation.

Several themes which emerge in the report deserve to be highlighted in this introduction.

The carefully understated article about Professor Hadwiger's research on the effect of chitosan treatment of seeds points up the importance of interaction between researchers and those concerned with the application of research results. Professor Hadwiger's research, with its potentially staggering agricultural and economic effects, is a classic case of the full spectrum of research/outreach which has been one of the noteworthy achievements of American science. Advisory field staff identified a resource problem: the disposal of crabshell waste. Researchers looked at a number of possible uses of a chemical derivative of the crabshell: chitosan. Professor Hadwiger found one such use, and in the process began to unravel some new information on the interactions between chitosan molecules and the crops studied. This information appears likely to lead to additional fundamental and applied research and ultimately to technology transfer to farmers and agribusinessmen.

Professor Hadwiger's work also illustrates the increasing importance of biotechnology, an area which encompasses the new capabilities of biology for altering the genes of organisms and even for the creation of new organisms and products. With only modest funds, the Sea Grant programs of this nation have made important contributions to the burgeoning field of marine biotechnology, and a brief suite of Washington's developing biotechnology effort is presented in this report. This area, which is likely to see considerable expansion in the future, holds tremendous promise in such areas as production of protein, new product development and pollution control.

In recent years the plight of the Pacific Northwest salmon fishery has received ever-increasing attention. Recent ratification of the U.S./Canada salmon treaty offers renewed hope that the seemingly inexorable decline of the salmon can be reversed. Toward this end, the Washington Sea Grant Program has been deeply involved in salmon enhancement since the program's inception. Some recent contributions are encapsulated in this report.

The health of Puget Sound has also been a source of recent public concern. In this area Washington Sea Grant has been a leader in providing useful and accurate information to resource managers and the concerned public. We will continue these efforts to provide information that allows the best use of scarce human and financial resources available for the stewardship of Puget Sound—and of our marine environment generally.

Throughout this report there is an emphasis on the role of public service in a program like Sea Grant. In addition to supporting the expected university functions of research and education, we have been charged by Congress to study critical marine resource problems and opportunities and to extend the resources of the university to those who use and manage these resources—the general public, business and industry, and management agencies. The public service research university is a uniquely American contribution to education, and Sea Grant is one of the most recent stages in the continued development of this concept. As I hope this report will demonstrate, so far the Sea Grant experiment has been a successful one.

Louie S. Echols
August 1985

Wheat Health & Chitosan

Farms bordering the coast have always gained when excesses of the sea were plowed into the earth. Dead fish and seaweeds return nutrients to the soil; broken shell leaches out minerals. Often storm-generated, such additions could be made, however, with the precision and predictability of a windfall in the forest.

But a new use of marine largesse in agriculture has more of the flavor of high tech than it does organic gardening. Plant pathologist Lee Hadwiger has taken as his marine additive waste crabshell that has been powdered, extracted, demineralized, and further altered chemically. And he's looked at the effects of the resulting compound, called chitosan, on plant growth and disease resistance not just at the whole-plant level but also at the molecular level.

Photo: Lee Hadwiger

Chitosan-treated wheat (left) grows upright and vigorous while untreated wheat (right) in a control plot breaks and falls before harvest time, reducing the yield.

Hadwiger, a professor at Washington State University in Pullman, has developed a winter wheat seed treatment using chitosan that helps protect the crop against damage by soil fungus. In field trials in an eastern Washington area where fungal root rot is common, crop yield from treated seed was up to 20 percent higher than yield from untreated seed.

And in an Oklahoma wheat-growing area where root rot seldom causes visible wheat damage, chitosan-treated wheat had more grain per head, giving a 10 percent increase in yield—and suggesting that its growth-enhancing effects are not due to suppression of fungus alone.

The new, inexpensive wheat seed treatment has virtues that go far beyond its yield-enhancing effect:

- It creates a new commercial use for chitosan, a component of the waste crabshell that is a disposal problem for seafood processors.
- It should improve sales prospects for a small Oregon firm now producing processed chitosan and its parent compound, chitin.
- Since chitosan is a naturally occurring compound, its use in agriculture should have none of the unexpected toxic or residual effects that sometimes occur with synthetic chemicals.
- And the research that made it possible is now generating information at the molecular level on the interactions between plants and disease.

Chitin and chitosan, structural components of shrimp, crab and lobster shell, are by-products of seafood processing. When traditional dumping methods were prohibited by the U.S. Environmental Protection Agency in the late 1970s, some processors had to pay to have the waste hauled away. In an effort to help them, Sea Grant researchers at many universities around the country launched a quest for commercial uses of the material.

The successes of their quest—perhaps best illustrated by Hadwiger's project—have aided an industry. On the West coast, Bioshell, Inc., a small company in Albany, Oregon, has been producing chitin and chitosan from waste shell since 1981. It now owns a patent on the seed treatment use of chitosan developed by Hadwiger.

Says Bioshell president Roger Kaye, "We're currently making arrangements for sales to a worldwide distributor of agricultural chemicals." The trade name for the product will be YEA, an acronym for "yield enhancing agent."

Kaye will not speculate on potential sales of chitosan for wheat seed treatment, but he notes that it will have particular value in areas like the Palouse area of eastern Washington, which are affected by the soil fungus *Cercosporella*, one cause of root rot.

Hadwiger explains that chitosan treatment can benefit wheat farmers in a second way: In some areas of eastern Washington, farmers may delay planting winter wheat in the fall to avoid the early development of root rot. Late-planted wheat plants are small and leave the soil exposed to the erosion of wind and rain. But wheat seed treated with chitosan can be planted earlier and will grow rapidly in the warm days of early fall, providing better soil protection.

And the treatment is inexpensive: Hadwiger estimates the cost of treatment to be about $20 per 160 acres of wheat.

As part of his research on

chitosan, Hadwiger is investigating the way this chemical reduces the effect of fungal rot on a crop plant. Chitosan may have a direct effect on soil fungi in the vicinity of the planted seed, and it stimulates the growth of wheat roots and shoots. As the seed germinates, a portion of the chitosan compound is taken up by the plant. In regions where root rotting is prevalent, treated wheat plants remain standing while untreated ones fall over prior to harvest (see photo).

Hadwiger's research group has determined that in peas, chitosan activates specific disease resistance genes. Conversely, when chitosan is applied to plant pathogenic fungi, gene function is suppressed. It appears that chitosan attaches to and overwhelms the small quantity of DNA (genetic material) in a fungal cell, suppressing its function. And in plant cells with 100 times as much DNA, the chitosan only alters DNA shape and as a result enhances its function.

These remarkable observations have resulted from just an initial look into chitosan's effects on plants at the molecular level. There will undoubtedly be further important discoveries made in Lee Hadwiger's laboratory. At Washington State University, the results have encouraged other scientists to investigate this compound. Drs. C. A. Ryan and A. Berryman have recently observed that chitosan can induce the synthesis of a wound protein in tomatoes and can induce production of monoterpene (a component of plant oils) in pine.

This project is a prime demonstration that applied and basic research are not mutually exclusive arenas but are, in fact, vital partners. And it is a fine example of research in biotechnology, a high priority of Sea Grant programs nationally.

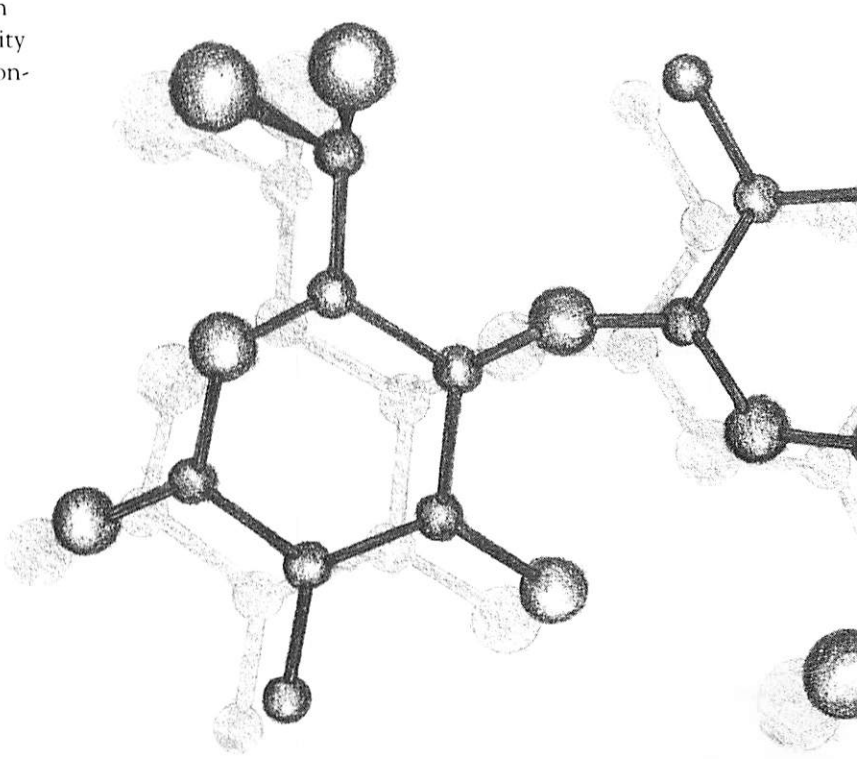
The Nature of Chitin

For those familiar with chitosan and its parent compound, chitin, in a marine context, Hadwiger's demonstration of its potency in the terrestrial world may seem a little strange. But the two compounds are not out of place there.

Chitin is the second most abundant polymer occurring in nature, after cellulose, with some 1600 metric tons produced annually. Like cellulose it is a polysaccharide—a compound formed of many identical simple sugar molecules. It is a structural component of the exoskeleton of insects and crustaceans—which are, in numbers at least, the most abundant animals on earth—and also occurs in the cell walls of fungi.

Chitin's key property is its ability to hold a strong positive charge, enabling it to bond easily with other materials. Its use as a clarifying agent is well-established, and researchers claim uses for everything from surgical sutures and burn dressings to contact lenses and as components of novel drug delivery systems.

But developing many of the higher-valued uses for chitin and chitosan will require further research commitment; two fundamental problems are not going to go away until this happens. These are, first, assuring a steady supply of raw material, and second, doing the careful chemistry needed to characterize the physical and chemical properties of the polymer.



Beginnings of Chitosan Research at the University of Washington

In 1969 John Liston and George Pigott, professors at University of Washington's Institute for Food Science and Technology, began a total utilization program. Their work, supported by Washington Sea Grant, was directed toward complete recovery of protein from seafood-processing wastes and development of marketable products from the waste. Two methods for extracting protein were eventually developed: one, using a brine solution and the other, enzyme hydrolysis.

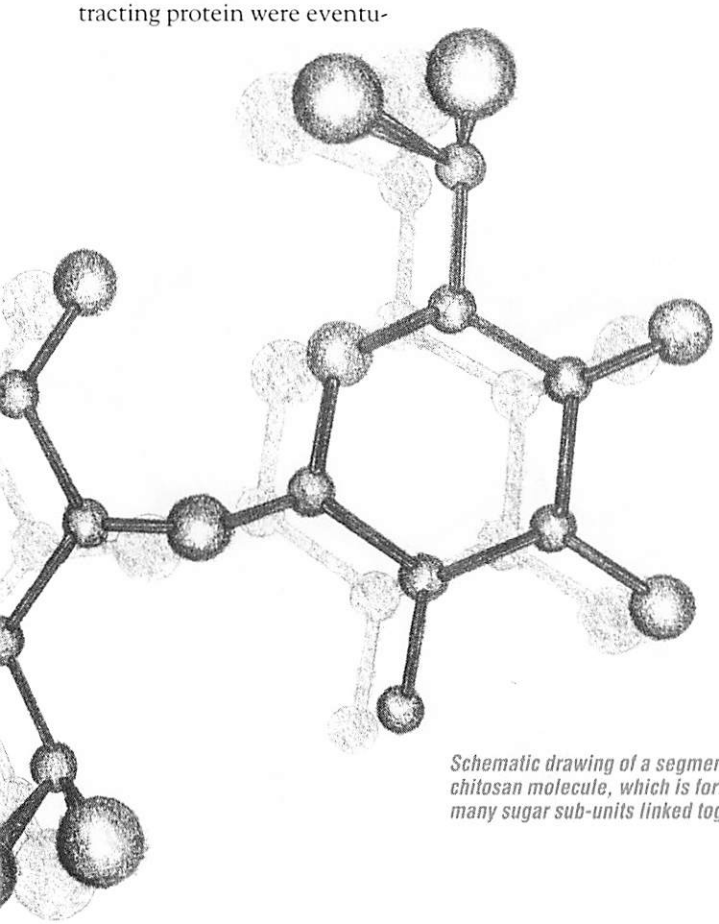
In a second Sea Grant project, professors Graham Allan of the University's College of Forest Resources and Darrel Medcalf of the Department of Chemistry at the University of Puget Sound, were investigating marine polymers including chitosan, a derivative of the chitinous material of shrimp and crab exoskeletons. Their work showed that chitosan probably had binding properties that would improve wet strength of paper during processing, a development that would interest the paper industry. Full-scale testing of these properties depended, however, on obtaining sufficient quantities of deproteinated shellfish waste from which chitosan could be extracted.

It was soon recognized that the deproteinated remains from Liston's and Pigott's research were the needed raw material for Allan's and Medcalf's. Coincidentally, Sea Grant's Marine Advisory Services seafood processing specialist at the time, Robert Palmateer, learned that a Seattle company was interested in establishing a scale model plant for producing chitin and chitosan from shrimp and crab wastes. The company had learned of newly-imposed Environmental Protection Agency regulations which prohibited seafood processors from dumping wastes around plants. Many processors were faced with finding some alternative means of treatment or disposal, or closing down.

Palmateer remembers, "One of the things we did with chitosan back then was to spray it into marine waters where divers were working. Because it attaches to particles and settles them out, it clears the water so the divers can see." Chitosan still is widely used as a flocculant.

By 1972 the Sea Grant researchers and their students were working in a pilot plant with personnel from Food, Chemical and Research Laboratories, Inc. (FCRL), to try to develop salable products from shrimp and crab processing wastes. To enable testing of chitin and chitosan in a wide variety of applications, the Oceanographic Institute of Washington distributed samples of the compounds to scientists in many disciplines, whose feedback helped the company determine which of the many potential applications had good market value.

Today, neither FCRL nor the Oceanographic Institute exists. But because of increased demand for chitosan created through Sea Grant-developed applications, two companies in the region—Bioshell, Inc., of Albany, Oregon, and another located in Redmond, Washington, which was recently acquired as a division of Protan, Inc., a Norwegian company—are producing chitin and chitosan for market.



Schematic drawing of a segment of a chitosan molecule, which is formed of many sugar sub-units linked together.

Illustration: Vicki Miles

In the Blink of an Eye
Changes at a Deep Sea Vent

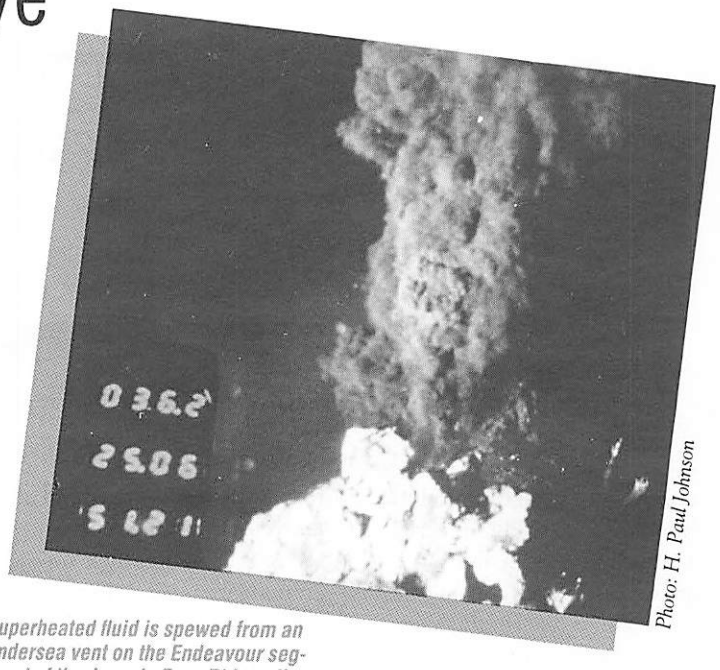


Photo: H. Paul Johnson

Superheated fluid is spewed from an undersea vent on the Endeavour segment of the Juan de Fuca Ridge off Vancouver Island.

In the late 1970s, the discovery of vents in the ocean floor emitting superheated fluid captured the attention of scientists, mining interests, and the general public. For geologists, the vents and their emissions were among the most tangible evidence yet found of the primal forces operating within the earth.

But measuring the activity of these ocean-bottom hot springs, in order to better understand sub-seabed geological processes, requires long-term observation—much longer than is possible during brief visits by manned submersibles. To lay the groundwork for such observation, two University of Washington oceanographers placed and tested monitoring instruments at a vent on the ocean floor off Vancouver Island, British Columbia, during a two-week research cruise in 1984.

One of the instruments, armed with electronic sensors and current meters, made repeated measurements of the chemistry, temperature and flow of superheated water issuing from the vent, giving researchers John Delaney and H. Paul Johnson a first glimpse of changes over time in these ocean-bottom hot springs.

Not only did the instruments work successfully, but the scientists' gamble—that some noticeable changes would occur over as short a period as a week—paid off. The second instrument, a time lapse camera, was focused on a one-meter-high chimney venting 56 degrees C (133 F) water and recorded mineral deposition occurring at a rate of six centimeters—more than two inches—per day.

The electronic sensors were placed at two different distances from the vent opening. The nearer sensor recorded temperatures varying between 9 and 16 degrees C (48 and 60 F) over several-hour periods. The more distant sensor recorded 2 to 2.5 degree C (35 to 37 F) temperatures, with the higher temperatures corresponding to times of stronger water flow. The researchers were able to rule out tides as causes of the water flow variations, and Delaney theorizes that physical changes in the fluids during superheating and cooling may be responsible.

Buoyed by this preliminary success, Delaney and Johnson plan longer deployments of similar instruments. "A week is a blink of an eye, geologically," Delaney acknowledges. "This initial effort was really a test of off-the-shelf instruments under new conditions. We need to develop instruments specifically for this application and put them down for a year or more. And eventually, we plan to have a permanent observatory at, or in, a vent."

Placing electronic instruments at a vent deep in the ocean required solving a number of problems. The vent monitoring instruments, which were paid for in part by Washington Sea Grant, were housed in a two-foot-diameter metal sphere which withstands high pressure at depth. The sphere, weighted by an anchor, was lowered to the bottom near a vent by wire from a ship. Then the manned submersible *Alvin*, based at Woods Hole Oceanographic Institution and made available through funds from the National Science Foundation, dived to the bottom, used a remote-controlled arm to move the sphere closer to a vent, and placed its sensors at or in the vent.

The time lapse camera, built with funds from both University of Washington and University of Victoria, British Columbia, was held in a separate framework and taken to the bottom by the submersible.

Alvin made a number of dives during the cruise, each time collecting water samples for comparison with the measurements being taken by the vent-monitoring instruments. During its final dive, guided by its pilot and two scientist-passengers, *Alvin* manually removed the pin attaching the anchor to the instrument sphere. A series of floats attached to the sphere then buoyed it to the surface, where its radio beacon and strobe light signalled its location to *Alvin*'s mother ship *R.V. Atlantis II* for recovery.

Testing for Shellfish Toxins

Washington is one state among several on both Atlantic and Pacific coasts that monitor shellfish for Paralytic Shellfish Poisoning, or PSP. Maine and Alaska also have state health laboratories that test commercial shellfish for PSP toxins and close beaches to recreational shellfish harvest if toxin levels become dangerous.

The test for PSP used by all the states and approved by the U.S. Food and Drug Administration (FDA) is a mouse bioassay. Mice are injected with extracts of shellfish tissue, and the time from injection to the mouse's last gasp is measured. Though straightforward, this is a tedious and expensive procedure, requiring careful observation of individual mice over time. If samples are too 'hot' and the mouse dies too quickly, then a technician must repeat the bioassay using increasingly dilute extract until the response falls within the established limits of the test.

An alternative chemical assay for PSP may soon be available, if current comparison tests by Washington's Department of Social and Health Services (DSHS) prove successful.

Former UW undergraduate Larry Wu and graduate student Jac Jonas-Davies developed the test in research directed by John Liston of University of Washington's Institute for Food Science and Technology. Run on an autoanalyzer—an instrument which automates a chemical test—the test is faster and easier to use than the mouse bioassay. Eventually it should enable laboratories to process a greater number of samples than before, according to DSHS microbiologist Laura Kentala.

Wu and Davies' accomplishment spun off from a sophisticated toxin-measuring method developed previously in their lab through the efforts of Dr. Wayne Iwaoka, now at the University of Hawaii, and Dr. John Sullivan, now with the Seattle laboratory of the U.S. Food and Drug Administration (FDA). The students separated the research method into two phases, one of which is automated for rapid routine analysis.

The automated phase of the test rapidly determines the sum total of shellfish toxins in each sample. Because of differences among the toxins of different shellfish, a second measurement of the toxin 'profile' in each batch of samples is needed to calibrate the results. This phase requires high-pressure liquid chromatography, done in research laboratories.

Working in collaboration with DSHS last summer, the UW researchers showed that the autoanalyzer test yields a toxicity determination which correlates well with the mouse bioassay.

"Probably 70 to 80 percent of the samples now tested in the mouse bioassay can be screened out using the autoanalyzer," estimates Liston. "The remaining 20 to 30 percent will have to be re-tested with mice because they fall within a critical range of toxin levels. But running the mouse bioassay on these samples is easier because of information about toxin concentrations gained from the autoanalyzer tests."

According to Kentala, the FDA has given DSHS the go-ahead for use of the autoanalyzer test on a limited basis. All current tests are backed up by mouse bioassays. And future use will be limited; the automated test will not replace the mouse bioassay for determining when a beach should be closed or re-opened to shellfishing, but it can be used for routine monitoring of closed beaches.

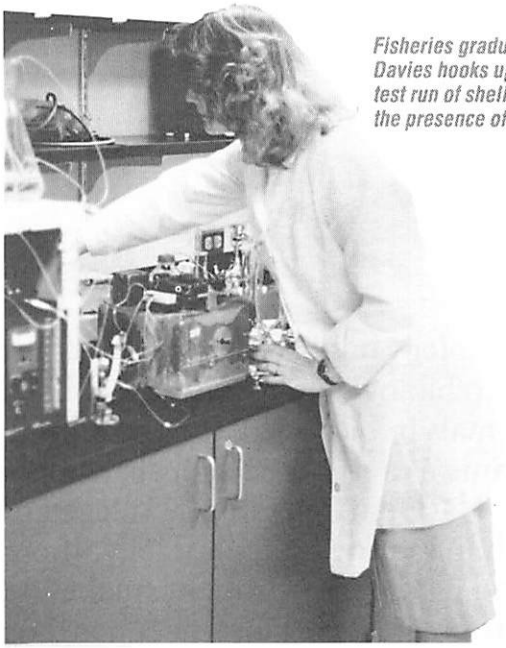
Even so, Kentala estimates that using the autoanalyzer will reduce significantly the number of mice used by the laboratory and will greatly speed up testing.

But the real advantage will be in providing greater service to the public. "We want to extend our shellfish testing service as much as possible. Right now, we have an understanding with the counties about how many samples they can send us for testing every other week. The new test will enable us eventually to monitor a larger geographic area and to monitor closed beaches more frequently than before," says Kentala.

Bloom or Bust: A Parasite Attacks PSP-Producing Phytoplankton . . .

While other Sea Grant researchers were developing a new detection method for PSP in shellfish, botanist Louisa Nishitani studied a parasitic species of phytoplankton that affects populations of the toxin-producing alga, *Gonyaulax catenella.*

During periods of blooms, or dense concentrations of



Fisheries graduate student Jac Jonas-Davies hooks up the autoanalyzer for a test run of shellfish extract to test for the presence of PSP toxins.

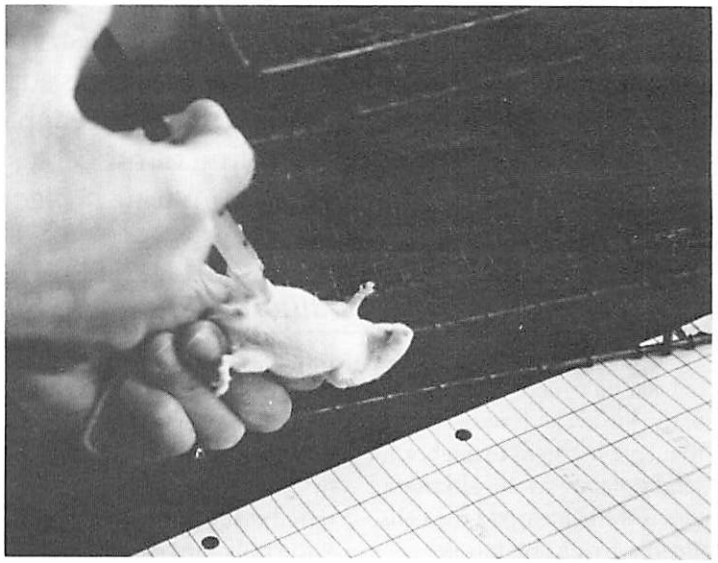


Photo: Laura Kentala

At the Seattle laboratory of the Washington Department of Social & Health Services, a lab mouse is injected with PSP extract. This is the FDA-approved bioassay for paralytic shellfish toxins and is used in Washington, Maine, Alaska and other states.

Gonyaulax, some of the cells may be invaded by the parasite. Could the parasite offer a means of controlling toxic blooms?

To investigate this possibility, Nishitani needed to determine what conditions lead to parasitism of *Gonyaulax*. Specifically, did *Gonyaulax* have to be in a weakened condition, such as occurs at the end of a bloom when nutrients in seawater have been reduced? From field observations, Nishitani determined that nutrient stress was not a necessary condition for parasitism.

Second, by monitoring *Gonyaulax* cells in the field before, during, and after blooms, she learned that when seawater conditions support rapidly developing blooms of *Gonyaulax*, the cells are much less likely to be heavily parasitized than when conditions favor slowly developing blooms; such blooms may even be held in check by parasitism.

The parasite was extremely effective in destroying *Gonyaulax* under laboratory conditions. But there's a catch: Nishitani also found it can attack a number of benign species of phytoplankton. So it does not bear out earlier hopes that it would make a good biological control agent for *Gonyaulax* in the field. However, Nishitani's work adds a new angle to our understanding of environmental factors influencing *Gonyaulax* population cycles. This area of study may help one day in predicting the occurrence of toxins in shellfish.

. . . and a Marine Advisory Report Fights Mis-Information

Dear Scientists,
I have conferred with five local doctors with combined experience of 127 years. Two live on Hood Canal, one in Seattle, one in Everett, one in Bellingham. My question to them was: Have you ever seen, treated or heard of a case of 'Red Tide Poisoning?' All answers were an absolute no.
Since I am of the opinion that the Department of Fisheries is using the 'Red Tide Scare' to close down various beaches to 'conserve the resource,' why don't they tell us the truth? Could you please document and supply a list of 'PSP' cases and dates?

From a letter to Washington Sea Grant written by a Washington resident, summer 1984

Folk tales and half truths concerning paralytic shellfish poisoning (PSP) abound. Perhaps this should not be surprising, considering the rarity of documented occurrences of the illness—only three deaths in Washington state since 1900, although in 1972 and 1978 some 15 to 20 non-fatal cases occurred. But since PSP is not required to be reported, these are very likely not all the cases.

To counter the spread of mis-information, and to aid the public in understanding this not-so-simple issue, in 1982 Washington Sea Grant produced a marine advisory report, "Gathering Safe Shellfish in Washington." It explains the phenomenon, describes the illness, and recounts the history of its occurrence in the state and region.

Written by University of Washington biologists Louisa Nishitani and Kenneth Chew, the report was reviewed by Department of Social and Health Services (DSHS) staff and two shellfish growers. It has been well-received, generating strong and steady numbers of requests from individuals and from state agencies such as DSHS and the Department of Parks, which in 1984 helped pay for a reprinting of 5,000 copies for distribution at state parks.

Because of its scientific accuracy and understandable language, "Gathering Safe Shellfish" has proved as well to be a resource for the local media. On several occasions, the report has been sent to inquiring reporters, and entire news stories have resulted.

Biotechnology has been defined as "the application of engineering principles to biological processes." While the use of terrestrial plants and animals in biotechnology is well-established, the potential of marine organisms and systems for such application has been little explored. The National Sea Grant College Program's support for academic research in marine biotechnology, though low in comparison to agricultural and medical investment, makes it the primary sponsor of research in certain areas, for instance, marine pharmacology and aquaculture.

Washington Sea Grant has been a consistent supporter of aquaculture research and development and recently has supported projects which, like Lee Hadwiger's work with chitosan, reach deep into molecular biology to develop an understanding of processes and relationships. On these pages we present reports from four projects.

Caulobacters in the Sea

Caulobacters are a genus of bacteria which, in one phase of the life cycle, have a stalk that enables them to anchor to solid surfaces. In the alternate phase of the life cycle the cells are free-living and motile. Found in both freshwater and seawater, caulobacters have been associated traditionally with nutritionally-poor environments.

Biochemist Nina Agabian and developmental microbiologist John Smit, who previously studied freshwater caulobacters, developed methods for working with marine ones. Though they have left University of Washington for California, Agabian's and Smit's preliminary work opens some intriguing research areas:

- Their study may help toward understanding and eventual control of biofouling, which marine caulobacters may help to initiate.
- And the caulobacters' attachment capability suggests that these organisms may have potential for use as marine pollutant detoxifiers—if it can be shown that genetic material enabling them to perform the detoxification can be transferred easily to them, and also if the stalk provides control over the "siting" of these organisms.

Agabian and Smit succeeded in culturing marine caulobacters from each of several seawater environments including:

- seawater tanks at University of Washington
- a sewage-polluted outflow into Puget Sound from an urban park
- marine waters along a suburban beach
- oil-slicked waters in a city harbor
- the cold and pristine waters of Washington's San Juan Islands
- two areas of Hood Canal, a deep natural inlet of Puget Sound

These findings suggest that caulobacters are widespread in marine waters and are not restricted to low-nutrient environments. And the researchers were able to culture marine caulobacters at several temperatures, including 30 degrees C (98 F)—again, counter to conventional wisdom which suggested that low temperatures would be essential.

Using biochemical techniques, Smit found that caulobacters from fresh and marine waters appear to have the same surface layer protein, one that does not occur on other marine bacteria. And a gene that codes for the cell's "tail" (flagellum) also appears to be common to both marine and freshwater caulobacters. Finally, in a very important step, he found preliminary evidence that a plasmid (a piece of genetic material separate from the main bacterial genes) from *E. coli*, the common intestinal bacteria that is the workhorse of genetic studies, can be transferred to this marine caulobacter.

Triploid Oysters: Next, to Market?

Marketing of many species of oysters virtually ceases in summer, when the mollusks' preparation for spawning results in an unappetizing abundance of gonad material and loss of firmness. To produce a "neutered" oyster—one with less interest in sex—fisheries graduate students Stan Allen and Sandy Downing and professors William Hershberger and Kenneth Chew have developed two methods of inducing triploidy, or multiple chromosome numbers, in oysters. Triploid oysters, it turns out, are either completely sterile or develop very little gonad.

Working in cooperation with Coast Oyster Company, Quilcene, Wash., and with the Pacific Coast Oyster Growers Association, the researchers found that treating oyster eggs soon after fertilization with the drug cytochalasin B induces triploidy in nearly all—90 to 100%—of the embryos.

A second method, high-pressure treatment of the eggs, also induces triploidy but with a lower rate of success.

In field trials in commercial beds in Puget Sound, the triploids grew at rates similar to those of normal diploid oysters. And, as expected, triploids develop little or no gonad; this was confirmed by examining triploids reared under fast-growth conditions in warmer California waters.

A potential obstacle to getting triploid oysters all the way to market was the need for Food and Drug Administration approval to use cytochalasin B for this purpose. However, the FDA ruled recently that the technique requires minimal use of the drug. Consequently, it has authorized drug manufacturers to sell cytochalasin B to oyster growers who follow Allen's and Downing's protocol.

Sterile Salmon

Now swimming out at sea and due to return home to Seattle's Elliott Bay in fall 1985 is a group of coho salmon whose chromosomes were altered early in development. These fish, and a companion experimental group held in seawater net pens in Puget Sound, will provide several local fisheries researchers with information about growth and behavior of fish that are triploid—that is, they have an extra set of chromosomes, making them partially or totally sterile.

Will the fish return along expected migration routes? Will they continue to grow past the time they would normally mature sexually? Answering these and other questions is the goal of biologists William Hershberger (University of Washington), Gary Thorgaard (Washington State University) and Fred Utter (National Marine Fisheries Service, Seattle).

The scientists are studying these fish because of their potential to enhance ocean and coastal fisheries. Triploid hybrids can be formed to develop fish for certain sport fisheries or to resist particular diseases.

The salmon eggs are heat-shocked at fertilization to make them triploid in chromosome number rather than the normal diploid. As with triploid oysters, triploid salmon develop either little or no gonad tissue. The technique is being tested with chinook and chum salmon and steelhead trout as well.

Some of the triploid cohos have been held in seawater net pens rather than released to sea, so that they can be monitored for physiological and biochemical effects of triploidy on growth and development. At eight months after smoltification, triploids were three percent longer and nearly three percent heavier in gutted weight than diploids. Levels of vitellogenin (a yolk protein), thyroid hormone and testosterone in the plasma of triploids were reduced relative to diploids; these changes did not appear to interfere with seawater adaptation.

And if the sterile salmon remain in the fishery rather than swimming upstream, fisheries managers will have an additional tool for enhancing fisheries rather than, as is true for some hatcheries, adding to already plentiful broodstock.

Fish Disease Prevention

A new approach to vaccine development employs the tools of genetic engineering where conventional techniques have failed. Using as a model the disease-causing bacterium *Vibrio anguillarum*, researcher Jorge Crosa and his co-workers at Oregon Health Sciences University have identified a protein in the surface structure of one strain of the bacterium which is a determinant of the strain's high virulence. They have shown that the genetic material coding for this protein can be manipulated in the laboratory.

This suggests the possibility, one which the researchers are now pursuing, that a strain can be "engineered" so that this surface protein component is amplified significantly. Such a strain should be much more likely than the original to provoke the strong antibody response needed to confer immunity on fish. If this approach succeeds, then it will be used to develop vaccines for such intractable fish diseases as furunculosis.

Photo: John Peters

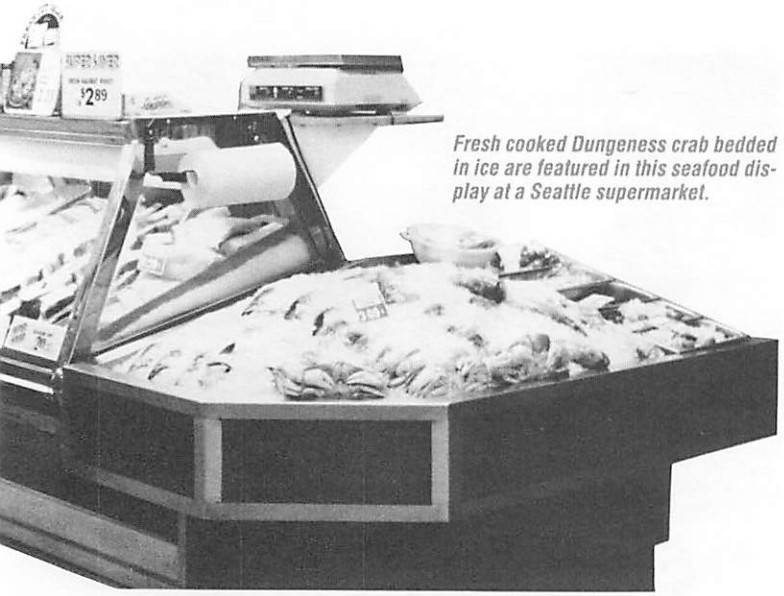
Seafood Quality

The American appetite for seafood has been whetted. The National Fisheries Institute reports that annual per capita consumption of seafood in the U.S. peaked in 1984 at 13.6 pounds—half a pound higher than the previous record. As a result, seafood retailers and supermarket managers are learning that it is essential to offer high quality products. Yet recognizing, maintaining and merchandising good quality seafoods are skills that must be learned.

To fill the gaps in many a retailer's knowledge of seafood, a team of Washington Sea Grant Marine Advisory personnel has presented seminars to explain and demonstrate the basics of seafood handling, merchandising, quality evaluation and sanitation. Attendance has ranged from "mom and pop" store owners to employees of major food chains.

Among the results: Haydens Phase II, a Bellingham-area supermarket, reassessed its philosophy about seafood, made dramatic physical renovations, and now boasts an attractive seafood section that features a wide variety of top quality products. The largest chain in the state, Safeway Stores, Inc., is improving its ability to handle and display seafood. One food chain store executive reports that as a result of changes made, "volume and profitability are up."

The retailing seminars have generated considerable interest outside Washington state as well. A new project—funded by the Alaska Seafood Marketing Institute and co-sponsored by the Pacific Sea Grant College Program (which besides Washington includes California, Oregon, Alaska and Hawaii)—will take the seminars on the road in 1986 to 16 west coast cities from San Diego to Fairbanks.



Fresh cooked Dungeness crab bedded in ice are featured in this seafood display at a Seattle supermarket.

Photo: John Peters

John Peters, Washington Sea Grant's seafood processing specialist, explains that the workshops will show retailers how to overcome consumer resistance and at the same time increase their own profits. He says, "Recent studies show that almost three-quarters of the seafood consumed in this country is eaten in restaurants. Consumers are often reluctant to buy food in supermarkets because they lack familiarity with species selection, quality characteristics, product preparation, and nutritional benefits of seafood. We want to show retailers how to remedy that situation."

Besides schooling the retailers, WSG Marine Advisory Services has tailored workshops for consumers wishing to learn to recognize quality and to handle seafood properly. The "Buying Seafood for Your Family" workshops, and an accompanying advisory brochure by the same name, were produced in response to growing consumer interest. The workshops include information on seafood products for specific uses, ways to prepare seafoods, and the best ways to benefit from seafoods' high nutritional values. The audience is given a hands-on session on quality determination, a cooking demonstration and sample taste tests.

Seafood processing specialist John Peters has been assisted in the workshops by field agents Jim Humphreys and Steve Harbell and by Evelyn Hansen, seafood consultant and member of National Seafood Educators.

ESTUARIES AS CRAB NURSERIES

Estuaries are known to provide protection and food for the young of many marine fishes and invertebrates. But whether they also play this role for an important West Coast crustacean, Dungeness crab, has never been entirely clear; while the adults, including egg-bearing females, are found almost exclusively offshore, the young-of-the-year and 1-year-old juveniles have been found both in offshore waters and in estuaries.

The question of estuaries and Dungeness crab has become a pressing one. Over the years, estuarine habitat has been lost or disturbed by development, and the pressure to develop continues.

The fishery itself has undergone a severe decline in recent years, but this may not be permanent; on the West coast, landings of Dungeness crab seem to cycle widely over 9-12 year periods. The cause of these fluctuations is not known. But habitat loss on top of such intrinsic volatility may be extremely damaging to the populations.

In a new project directed by David A. Armstrong and Donald R. Gunderson, both faculty at University of Washington, the question of estuaries and young Dungeness crab is addressed head-on. For two years the scientists have conducted intensive surveys for young crab in Grays Harbor estuary on Washington's Pacific coast, and in adjacent offshore waters.

Photo: Brett Dumbauld

David Armstrong, searches for young-of-the-year crab among shellhash and eelgrass of an intertidal area in Grays Harbor estuary.

They now have good evidence that estuaries are indeed important nursery grounds for Dungeness crab; three to four times as many first-year crabs were found to live in the estuary as live offshore in summer. This was true despite the larger area offshore than in the estuary.

Young-of-the-year crabs that live in the estuary in summer also grow much faster than those offshore, the scientists learned. And they found that protected intertidal areas of Grays Harbor provide an important haven from predators for the thumbtack-sized young crabs.

"We've seen small crabs at initial densities in excess of 500 per square meter in tidepools with shell debris," Armstrong says. Areas of eelgrass and stick debris also provide cover for large numbers of juveniles. Armstrong's appreciation of the need for protective cover was reinforced when his six-year-old son, accompanying him on a weekend outing, pointed to seagull droppings full of tiny, undigested crab remains.

Besides the intertidal areas, certain subtidal areas away from the main navigation channel also support large ju-

Photo: David Armstrong

Low tide reveals this network of channels in Grays Harbor estuary, site of research on the importance of estuaries to young-of-the-year Dungeness crab.

venile populations. The researchers are mapping the various habitat types to determine their overall importance to the juvenile crabs.

Armstrong, Gunderson, and graduate students Chris Rogers and Ken Carassco conducted the in-estuary surveys every month from April to November of 1983 and 1984, and the work is continuing in 1985. A specially-designed beam trawl, hauled from a motorboat that can navigate shallow channels, was used to sample subtidal areas. Areas above the water were surveyed on foot.

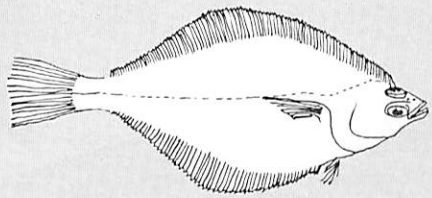
Offshore stations—off Copalis Head, Grays Harbor, and the mouth of Willapa Bay—were monitored less frequently. Preliminary results reveal several hundred times as many young crabs in the 10- to 20-fathom range as in either shallower or deeper waters. This finding could affect future work by the U.S. Army Corps of Engineers, which is considering offshore sites for disposing of dredge material.

Grays Harbor was a natural choice for the study because its main navigation channel is dredged yearly by the Corps of Engineers, and there are plans to widen and deepen the channel. Concerned about dredging effects on crab, the Corps funded an earlier study by Armstrong which pointed to the need for information about juvenile crab habitat needs. The Corps currently is funding an additional part of the study which uses a hovercraft to map intertidal areas.

The information on juvenile habitat use is also extremely valuable to Washington's Department of Fisheries which evaluates potential impact on fisheries of development projects in state waters.

Armstrong and Gunderson expect, but can't be certain, that they will be able to extend their conclusions about crab habitat in Grays Harbor to other estuaries. They have begun sampling in Puget Sound and added stations in Willapa Bay, an even larger Pacific coast estuary south of Grays Harbor, in 1985.

Additional work in 1985 and thereafter will look at the effects of other factors, including changes in the physical environment, on crab populations. These studies are essential to long-term management and conservation of Washington's Dungeness crab resource.



...and Sole Nurseries, too

During the Grays Harbor and coastal surveys for juvenile Dungeness crab, graduate student Chris Rogers recorded numbers and sizes of young flatfish hauled up by the beam trawl. Among several species of flatfish that were seen regularly, English sole juveniles were the most similar to Dungeness crabs in their apparent use of the estuary as a nursery.

Rogers determined that as many young sole were living in the estuary as lived in an offshore area 18 times the estuary's size. This suggested that the resources of the estuary, in fact, can support young fish living at much higher densities than offshore.

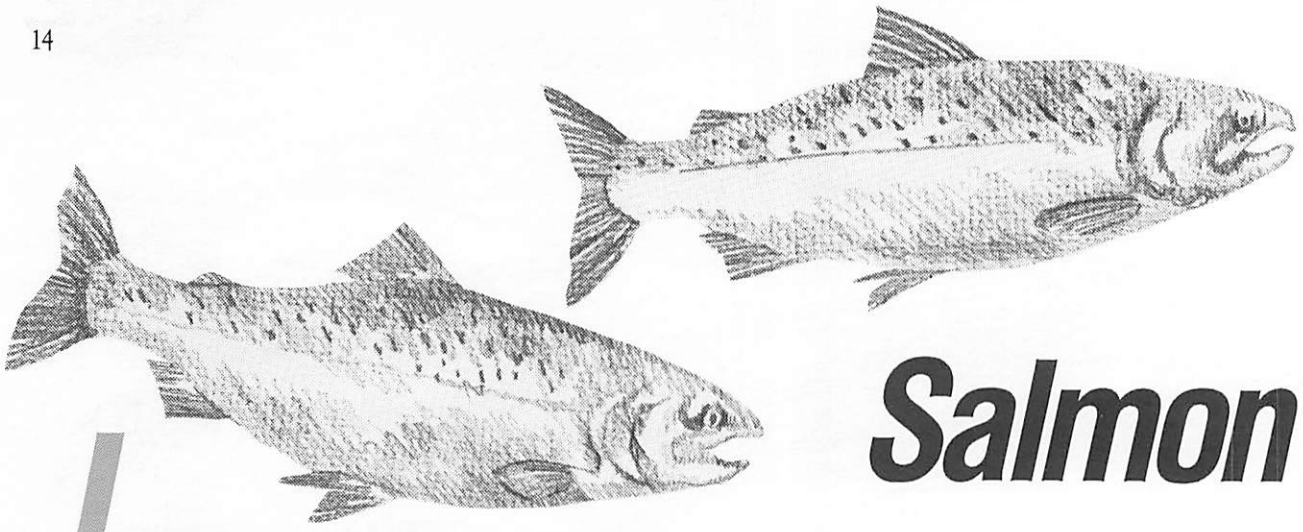
Rogers also found that the two years of his study, 1982 and 1983, were very different. In 1983 he estimated that 8 million young sole had settled in the two areas. In 1984 his estimate soared to 42 million.

"This dramatic difference in recruitment from year to year could show up eventually in the commercial fishery," says Don Gunderson, a co-investigator on the crab project and Rogers's thesis advisor. He explains that fisheries biologists believe that most pre-harvest mortality occurs during the egg, larval and juvenile stages. If this holds true, then surveying numbers of young fish produced each year could provide some predictive capability for the fishery. For English sole, a prediction could be made well in advance, since the fish do not reach harvestable size for three to five years.

English sole are taken in the commercial groundfish fishery off Oregon and Washington. In 1983 the combined harvest off the coasts of the two states was valued at about $30 million, and a significant fraction of this was flatfish. But the resource appears to be on the decline, giving fisheries managers even greater incentive to incorporate into their assessment this new information on the habitat needs of the young fish.

Will estuarine modification, such as dredging of Grays Harbor, affect numbers of young fish produced? According to Rogers, permanent loss or degradation of tidal flats could reduce numbers of young fish the estuary can support.

And the question of whether lost habitat can be replaced or compensated for still needs to be addressed. Until it is, conflicts between would-be protectors of estuaries and those who would develop them will continue.



Salmon

It was a series of unrelated and inadvertent human steps that led, over many decades, to a decline in salmon resources in Washington and many parts of the nation. The building of dams, deteriorating water quality, losses of spawning habitat, changes in fishing techniques and effort—all these combined to undermine the security of once-self-maintaining stocks. To stem the decline of this resource similarly requires human intervention—this time deliberate—along several different fronts.

Hatchery Management

Computer-aided hatchery production. Now being evaluated at six Washington Department of Game trout hatcheries is a computer program to assist at every decision point in fish production. The program for personal computers developed by George Klontz at University of Idaho requires detailed input: physical and chemical characteristics of hatchery waters; size, weight, numbers and species of trout or salmon being reared; and food type used. The output is equally detailed: a hatchery manager can project weights of fish and number of days to reach a certain size; when a pond of fish should be split to maximize weight gain; costs of rearing; food requirements; and probable final number of fish. The hatchery manager can also track and evaluate the progress of fish during rearing.

Detecting smoltification. The difficulty of determining when juvenile hatchery salmon are ready for transfer from freshwater to seawater has frustrated managers for years. It also reduces production, since fish released to streams before they are ready for seaward migration suffer increased mortality. Researchers have been unable to find a simple, unambiguous indicator of smoltification, the physiological change juvenile salmon undergo to be able to live in seawater.

Employees of the Washington Department of Game steelhead hatcheries learn to use George I, the hatchery management software developed by Washington State University Professor G. W. "Bill" Klontz for personal computers.

Photo: Vicki Miles

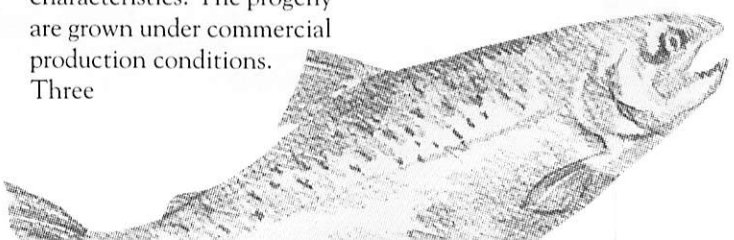
A technique now viewed with some optimism, however, is measuring thyroid hormone levels over time in a population of juvenile salmon. Endocrinologist Walton Dickhoff of University of Washington's School of Fisheries has shown that a pulse of thyroid hormone seems to occur in the blood of smolting coho salmon. Experiments now underway will test whether salmon released after the thyroid pulse survive in greater numbers than those released at other times.

Net Pen Production

Coho strain selection. Rearing Pacific salmon in net pens is a relatively new approach in salmon production. One goal is to develop a coho salmon stock suited to pen culture using selective breeding techniques. Desired traits include rapid growth in freshwater and seawater, good survival to maturity, high fecundity, and high yields at processing.

Working with two coho "families" at a commercial net-pen operation in Puget Sound, geneticists William Hershberger and Robert Iwamoto mate fish with high fecundity, high offspring viability and large egg size as well as good growth characteristics. The progeny are grown under commercial production conditions. Three generations of selection, combined with improvements in husbandry, have resulted in increased freshwater and seawater growth rates, greater success in smoltification, and better adult survival. These improvements led for the first time in 1982 and 1983 to more-than-adequate egg production for the facility's needs, ensuring continued genetic improvements.

Broodstock nutrition. A second goal of net-pen salmon research is to put the vitamin supplements fed to female broodfish on a scientific basis. Working at a commercial net-pen facility, Ronald Hardy has determined that increasing vitamin levels in the females' feed can result in higher levels of some vitamins in the eggs and higher egg production. To determine optimum vitamin levels, the researchers supplement broodstock feed with varying amounts of vitamins and then measure the activity of vitamin-dependent enzymes of the females as well as the number of eggs produced and egg vitamin content. In contrast to the current practice of simply doubling the juvenile vitamin supplement when feeding adult broodstock, this approach avoids unnecessary and costly increases in vitamin supplements.



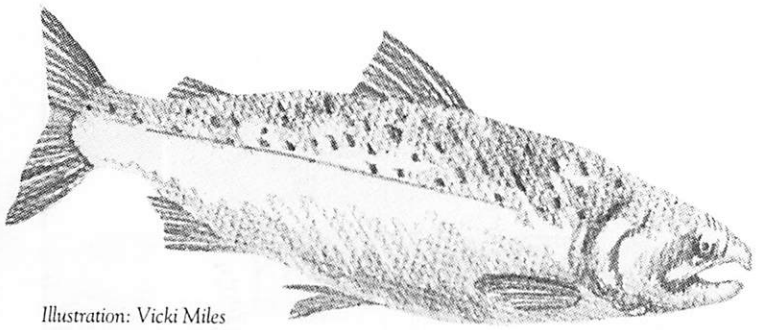


Illustration: Vicki Miles

Education

Grays Harbor College, located in Aberdeen, near Washington's Pacific coast, has provided training in aquaculture at the community college level since 1972. Its main aquaculture facility is a salmon hatchery which has produced some 40,000 to 150,000 coho salmon eggs each year for local release.

To provide facilities for rearing 100,000 cohos for 18 months (when they reach marketable size), the College constructed a new 20-by-20 foot pen-rearing facility with automatic feeders. It also added three nets for the containment of salmon fingerlings, a fenced access ramp, and a shoreside dock. Washington Sea Grant joined Grays Harbor County in providing funds for the facilities.

The addition of the new floating pen permitted the rearing of 400,000 coho salmon eggs in 1984 and 600,000 in 1985. The excess over the 100,000 reared in the net pen was planted, with guidance from the Washington Department of Fisheries, in small creeks which feed into Grays Harbor and which have not had salmon runs for over 75 years. This should benefit the local fishery as well as contributing to the training of students.

Disease Control

If unchecked, bacterial kidney disease (BKD) may kill up to 40 percent of spawners and reduce the production of young fish at hatcheries. It is a particularly difficult disease to eradicate from hatcheries, because BKD, although usually fatal in the long run, can be carried by fish for years and can be transmitted directly to offspring via the egg. George Klontz, University of Idaho, has developed an effective treatment for BKD—adult fish are injected with the antibiotic erythromycin, while eggs are immersed in a solution of the antibiotic. The two-part treatment eliminates BKD-causing bacteria from apparently healthy "carrier" fish and so prevents disease transmission after the fish have been released. Use of the treatment at hatcheries has reduced BKD-caused losses of adults to five percent or less.

Information Exchange

Efforts by its Marine Advisory Services resulted in Washington Sea Grant-sponsored workshops on salmonid broodstock maturation in 1980 and 1981 and a full-scale international symposium on salmonid reproduction in 1983. At the earlier workshops, which were organized by aquaculture specialist Terry Nosho, researchers and resource managers identified critical research needs and exchanged information leading to direct improvements in husbandry.

The symposium on salmonid reproduction was held at a time when researchers around the world had developed a variety of techniques permitting an unprecedented degree of control over salmon and trout life cycles. That this research area was ripe for discussion, evaluation and comparison of results was amply confirmed in the nearly 300 people attending, the quality of papers presented, and the participation by scientists from ten countries. Besides Washington Sea Grant, sponsors of the symposium were the Pacific Sea Grant College Program, the National Marine Fisheries Service and U.S. Fish & Wildlife Service.

The proceedings resulting from both workshops and symposium are further ensuring worldwide appreciation and understanding of progress in these areas of research.

The realization that concerted effort could halt the decline in salmon stocks came early in the Northwest and was evident in the building of the first hatchery in Washington state on the Kalama River in 1895. Yet incomplete understanding of salmon biology and continued habitat loss limited the success of the early efforts. With increased information on both the biological requirements and genetic plasticity of Pacific salmon have come improvements in traditional culture methods, new culture methods, and even the realization that new strains of salmon can be developed for particular uses. However, the continuing problems of the salmon fisheries suggest that much remains to be learned. Progress in some research areas is slow, its rate limited by the growth and maturation rates of the fish themselves. Yet the strides made thus far suggest that this multiple-front effort is a productive, even essential approach to securing salmon resources in the region.

Walton Dickhoff, School of Fisheries endocrinologist, holds young salmon which he will test for hormone levels indicating readiness for seawater.

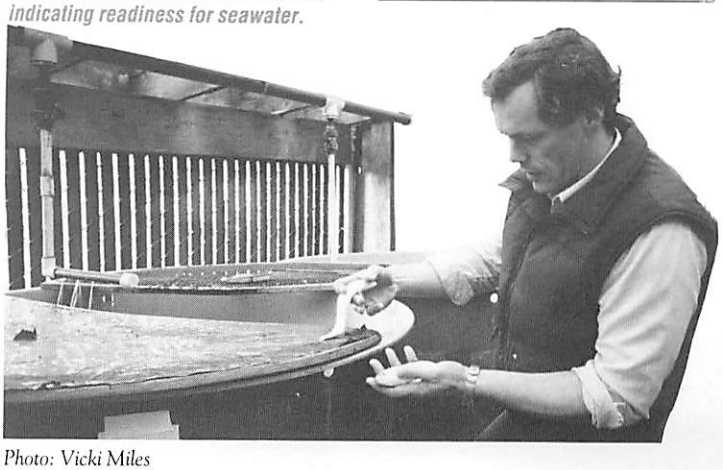
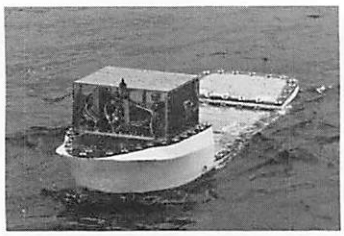
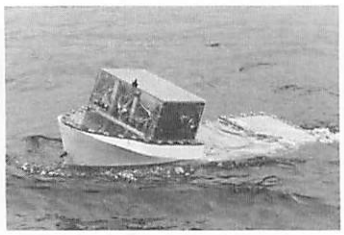
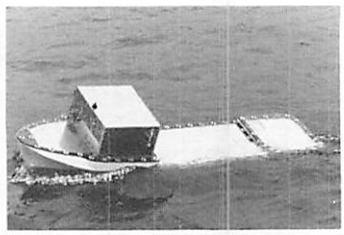


Photo: Vicki Miles



Rules for Rolls

Bruce Adee, professor of mechanical engineering and head of the Fishing Vessel Safety Center at the University of Washington, has studied vessel stability for years. He investigated the sinkings of two Alaskan crab boats, the Altair *and its sister ship* Americus, *as well as other less-publicized capsizings. From this work he has come up with a number of guidelines for vessel operators.*

Weight matters! Adee's first admonition is to keep track of a boat's weight. Over years of use, changing and adding gear make a vessel heavier and may shift its center of gravity. One clue to a boat's stability is freeboard, which Adee advises vessel operators to watch. The less freeboard, or the lower the deck is to the water, the less stable is the boat.

The threat of a following sea. Boats capsize easily in following seas, but almost never do in a bow quarter sea. Making a turn in a following sea can be particularly tricky. Adee advises operators: *Don't speed up.* Slow down, cut power, keep the rudder amidship.

Fuel tanks and fish holds. These offer tremendous potential for stability problems. When tanks and holds are filled, weight is added and the center of gravity is affected. Adee suggests keeping the double bottom fuel tanks of crab boats full at all times, because of their critical effects on stability. On the subject of fuel management, he advises keeping as many tanks as possible completely full or completely empty.

Ice. Vessel operators should be aware of weather conditions ahead of them that may lead to icing; loading and catch can be adjusted if icing is anticipated. Ice buildup during fishing should be monitored.

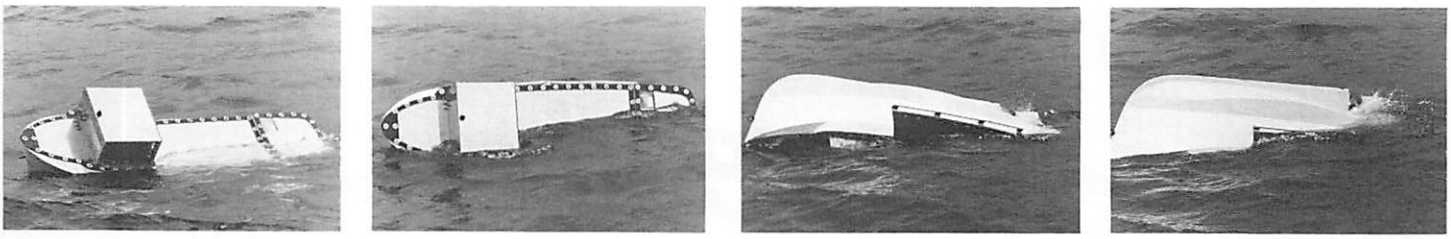
Seine boats. These deserve stability evaluation, Adee says: they are small, which in itself may be a problem; they are rarely tested for stability; and some have added new circulating seawater tanks.

Converting vessels. Because adding and changing gear on a boat to equip it for a new fishery affects stability, Adee recommends a complete stability test *before* the work is done. Then the safety of the conversion can be analyzed and assessed ahead of time, and unsafe projects avoided.

Sister ship stability tests? Adee recommends that boat operators not use the results of stability tests made on a sister ship for their own vessel unless their dead weights are the same. And if an operator does have a stability test performed, it should include calculations for anticipated loading conditions.

Reprinted from *Pacific Fishing.*

A test run and capsize of the crab boat model.



Photos: Mary Levin

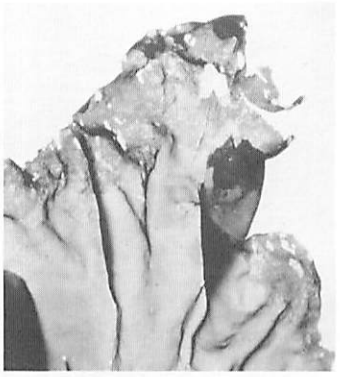
Clues to Crab Boat Capsizings

Two crab boats built as part of a series of seven sister ships were fishing out of Dutch Harbor, Alaska, when they capsized in the Bering Sea in February, 1983. University of Washington researcher Bruce Adee's investigations of loading conditions and stability of the crab boats, the *Altair* and the *Americus*, led to a discovery of 50 tons of unexplained weight on the vessels. This unexplained weight, along with known additions of 35 tons of drag gear and 70 tons of crab pots, made the boats unstable, a lengthy Coast Guard investigation concluded in August, 1985.

To determine what factors contributed to the capsizings, Adee carefully pieced together information from sister ships of the lost vessels. He compared "before" data for the *Antares*, the only sister ship whose weight and stability characteristics had been measured when it was new, with "after" data for *Morning Star*, a vessel that, like the capsized vessels, had been converted for trawling.

What Adee found was an extra 50 tons of weight. His studies of photographs of the two crab boats taken prior to the capsizings served to confirm the finding of added weight. Recounts Adee, "This discovery changed the whole focus of the Coast Guard investigations. Before, we couldn't explain what had happened. With this information, the capsizings were reasonable."

Adee is developing further his understanding of stability of the crab boats by studying the behavior of an eight-foot scale model. Equipped with remote controls and wired with electronic sensors to record its movements, accelerations, rudder angle, engine speed and heading, the boat can be tested under various wind, sea and loading conditions. On these pages is shown one of the test runs of the model.



Keys to Seaweed Spore Release . . .

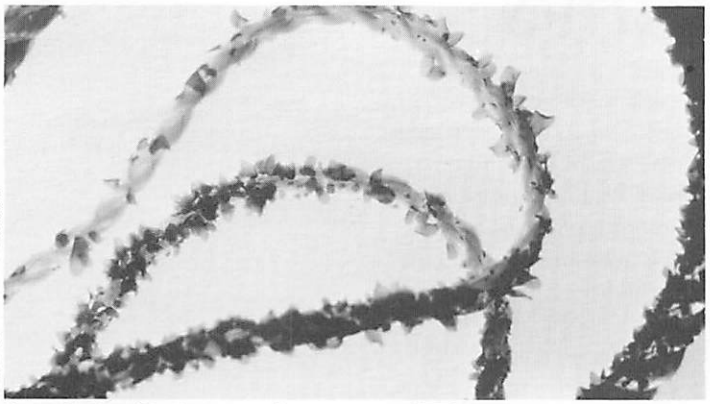


Photo: J. Robert Waaland

Young blades of Porphyra *grow from ropes that have been seeded with the conchospores of the seaweed.*

Being able to generate supplies of "seed" is as important to farming the sea as it is to farming the land. For current seaweed-culturing efforts to succeed in Puget Sound and elsewhere, growers need to know what conditions trigger spore release by the seaweeds.

The seaweed *Porphyra*, called nori when it is processed into paper-thin sheets for wrapping sushi, has been cultured in Japan for many years. The requirements for spore-release by Japanese species of *Porphyra* are known, and these have provided University of Washington botanist J. Robert Waaland with a basis for experiments using native Puget Sound *Porphyra* species.

In laboratory experiments, Waaland and his coworkers have found the natives differ in a number of ways from Japanese species. The conditions of temperature, light intensity and daylength that induce spore maturation and release are not only quite different from those associated with the Japanese species but also differ among the native species.

One local seaweed, in particular, is a maverick. Careful laboratory work by research associate Leal Dickson revealed that *Porphyra nereocystis*, a species that makes excellent-tasting nori, has a dual-daylength requirement for spore maturation and release; the seaweed must be exposed to a period of short days followed by a period of long days.

This is the first seaweed found to have a dual-daylength requirement, Waaland notes, adding that only 50 species of land plants have such a requirement. Like the land plants, *P. nereocystis* takes a very long time—20 or 30 days—to respond to the second daylength. When spore release finally occurs, it 'dribbles' at a slow and steady pace.

In constrast to *nereocystis*, another local species, *P. perforata*, responded so readily to laboratory manipulations that within six weeks of achieving sporulation in the laboratory, researchers were able to seed nets in the field.

According to Thomas Mumford, a state Department of Natural Resources biologist who has conducted growth trials for Waaland's cultures in different parts of Puget Sound, the natives are largely amenable to the same equipment and handling techniques developed for large scale nori culture in Japan. One difference: the native seaweed's microscopic conchocelis phase (the phase that releases the spores and is generally cultured in oyster shells) needs to be grown at much cooler water temperatures than Japanese species.

Among the species Waaland has studied are ones found in Puget Sound in different seasons—*P. torta* in winter, *P. perforata* in spring, *P. abbottae* during most of the year. As a result, it should be possible to develop a multi-crop system in which a grower's nets are supporting crops of *Porphyra* at nearly all times of year.

·Special Recognition·

All in the line of duty, these Marine Advisory Services staff members might say. But recent recognition of the work of three Washington Sea Grant specialists brings welcome attention to the strength of their programs and a "job well done" from their retiring director.

Thomas J. Dowd, Sea Grant port industries specialist and affiliate professor at the University of Washington Institute for Marine Studies, was named a Member of the Chartered Institute of Transport of Great Britain. This organization, founded in London in 1919, was subsequently granted a Royal Charter "to promote, encourage, and coordinate the study and advancement of the science and art of transport in all its branches." Although headquartered in Great Britain, the Institute has branches in the U.S. and other countries.

Dowd is a force behind the University of Washington's Port Management/Marine Transportation Program, one of three such programs in the world and the only one in the United States. He is the author of two recent Sea Grant publications: *Container Terminal Leasing/Pricing Methods and Their Economic Effects*, and *Port Management Control System—A Simplified Decision-making Tool.*

Robert Goodwin, coastal resources specialist for Washington Sea Grant, was named an honorary member of the Pacific Coast Congress of Harbormasters and Port Managers. The Congress, headquartered in Newport, Oregon, encourages development of marinas and harbors along sound economic lines. It also recommends policies and plans uniform operation and management of marinas and harbor facilities and aids in exchange of information about these subjects.

Goodwin, trained in geography, has written publications including: *Recreational Boating in Washington's Coastal Zone, Waterfront Revitalization: Plans and Projects in Six Washington Cities,* and *Contributions to Public Smallcraft Harbors to Washington's State and Local Economies*. Goodwin also has worked with local governments and the state Department of Ecology on issues and policy questions relating to shorelines management.

Michael S. Spranger, marine resources specialist for Washington Sea Grant and Washington State University Cooperative Extension, was presented the Outstanding Extension Program Award by the American Agricultural Economics Association, Western Region, at its July meeting in San Diego. Spranger received the award for his work with the Sea Grant Columbia/Snake River Program administered by a consortium of the University of Washington, Washington State University, Oregon State University, and the University of Idaho. He has led a public education program on the economic and social values of the Columbia/Snake River System and has provided continuing assistance in the economic development of river port districts.

Editor's Note: As this report was going to press, Michael Spranger was named marine advisory leader for the Washington Sea Grant Program effective October 15, 1985.

Robert E. Harris, director of Washington Sea Grant's marine advisory service since 1969, is retiring in December 1985. Among the nation's thirty marine advisory leaders, Harris is the longest serving, and his experience and integrity are valued throughout the national and regional Sea Grant networks by those who rely upon him for advice and "making things work". Under his leadership, Washington's marine advisory program was begun and became a cohesive team of subject matter specialists and field agents who serve the needs of Washington's varied marine constituencies—from salmon growers and seafood processors to port managers and operators of small coastal businesses.

The Sea Grant years were a second career for Bob Harris. From 1936 to 1968, he served in the U.S. Navy and retired from his post of supervisor of shipbuilding 13th district with the rank of captain. A 1940 graduate of the U.S. Naval Academy, Harris received a master's degree in naval construction and engineering from Massachusetts Institute of Technology.

Bob Harris will be sorely missed. He leaves behind him a vibrant advisory service program.

Sound INFORMATION

Few environments have been studied so long and so intensively as Puget Sound has been studied by scientists and scholars at the University of Washington.

In 1904, the University established the Puget Sound Marine Station—today known as Friday Harbor Laboratories—dedicated to the systematic study of the biology of the State's inshore marine waters, principally Puget Sound. Fifteen years after the opening of the marine station, a number of faculty on the main campus helped establish a college to study the fisheries of Puget Sound and other Washington waters.

Impelled by a National Academy of Sciences report emphasizing the country's lack of knowledge about the ocean, the University's Board of Regents created in the early 1930s the forerunner of what is now the School of Oceanography. Shortly, thereafter, research vessels began collecting data on the quality of Puget Sound waters. By 1952, regular monthly cruises were being launched to measure various physical and chemical properties of 81 stations on the Sound.

For the most part, the information derived from these many studies of Puget Sound found its way into scientific journals. Some of it, however, lay in archives awaiting recognition of its potential value and diverse uses.

In 1966, Congress passed the National Sea Grant College and Program Act and in 1968, the University received one of the first three grants under that act. It was this seminal legislation that led among other things to the means for compiling and actively disseminating the historic data and analyses of Puget Sound. With Sea Grant came a mechanism for publishing the extensive body of Puget Sound information that had been accumulating.

Responding to the nationwide push for environmental baseline information that characterized the early 1970s, Washington Sea Grant supported the work of oceanographers Alyn Duxbury and Eugene Collias, cartographer Noel McGary, and Puget Sound model builder John Lincoln to develop a series of books that brought together a significant body of Puget Sound data in usable formats. The first of these was the *Atlas of Physical and Chemical Properties of Puget Sound and Its Approaches,* a volume that charted measurements made between 1952 and 1966 of six water properties—temperature, salinity, density, dissolved oxygen, oxygen saturation, and dissolved inorganic phosphate. The Atlas was followed by an annotated bibliography of scientific literature on Puget Sound and an index to the regional oceanographic data collected between 1932 and 1966. All three volumes quickly became "standards" on the shelves of agencies and firms concerned with Puget Sound water quality. And they are still being used as baseline data by water quality managers and analysts.

Paralleling the publication of historic oceanographic data was that of other related literature. A 1971 class report written by students in Professor Juris Vagners's course in systems engineering was transformed into a book, *Oil on Puget Sound.* A 1975 study—*Coastal Resource Use: Decisions on Puget Sound* written by five UW professors in economics, urban affairs, political science and geography—documented the Sound's use patterns, its trends and conflicts, as well as the legal and political structures through which regional resource use decisions were made. The book was widely influential—in Puget Sound and elsewhere, too—as a model of multidisciplinary study of regional management.

Up until the mid 1970s the books were aimed primarily at scientific and technical readers. At that time, it became apparent that much available information might have a broader public appeal. It was Puget Sound's recreational divers and boaters who became avid fans of two books published in 1976 and 1977. A *Field Guide to the Fish of Puget Sound and the Northwest Coast* provides divers with descriptive text and drawings of 99 fish species common to the region. Instead of paper, the handy booklet is printed on a waterproof stock called "tyvec" and bound with stainless steel staples to prevent rusting from use in wet places! *Tideprints: Surface Tidal Currents in Puget Sound* was not conceived as a book for sailors—originally its contents were intended for use by the Environmental Protection Agency who needed to predict ways surface pollutants are dispersed in the Sound at various stages of the tide. But with help from Sea Grant, the original research data were charted and published much to the benefit of local sailors.

Over time, the circumstances behind each of these books forged a working partnership between oceanographer Alyn Duxbury and editor Patricia Peyton. It was the scientist—Duxbury—who first recognized the need for and urged the development of a comprehensive series of "monographs" describing the physical and biological aspects of Puget Sound. It was the edi-

tor—Peyton—who insisted that the "monographs" be published as readable books and sold through bookstores.

Together the pair sought and received in 1977 a grant from the Marine EcoSystem Analysis (MESA) project of the National Oceanic and Atmospheric Administration. Ultimately funding was also received from the Environmental Protection Agency and the National Sea Grant Program in support of a multi-volume series of Puget Sound Books.

A staff was assembled including editor Andrea Jarvela and graphic designer Kirk Johnson. An editorial board representing an array of Puget Sound interests was appointed. A marketing agreement was struck with the University of Washington Press. Authors were sought throughout the Puget Sound community. They ranged from scientists who had an aptitude for writing to writers who had an aptitude for science and social science. Writing contracts were signed. And the work began.

Volume one appeared in October 1981. Significantly, it was Daniel Jack Chasan's historical overview: *The Water Link: A History of Puget Sound as a Resource.* The book was hailed by Northwest historian Murray Morgan as "a brilliant achievement" and "a triumph of historical reportage." He wrote, "Chasan's prose is solid with fact, lively with quotation, and shot through with informed judgment," but Morgan railed "My only complaint is that the book should be twice as long."

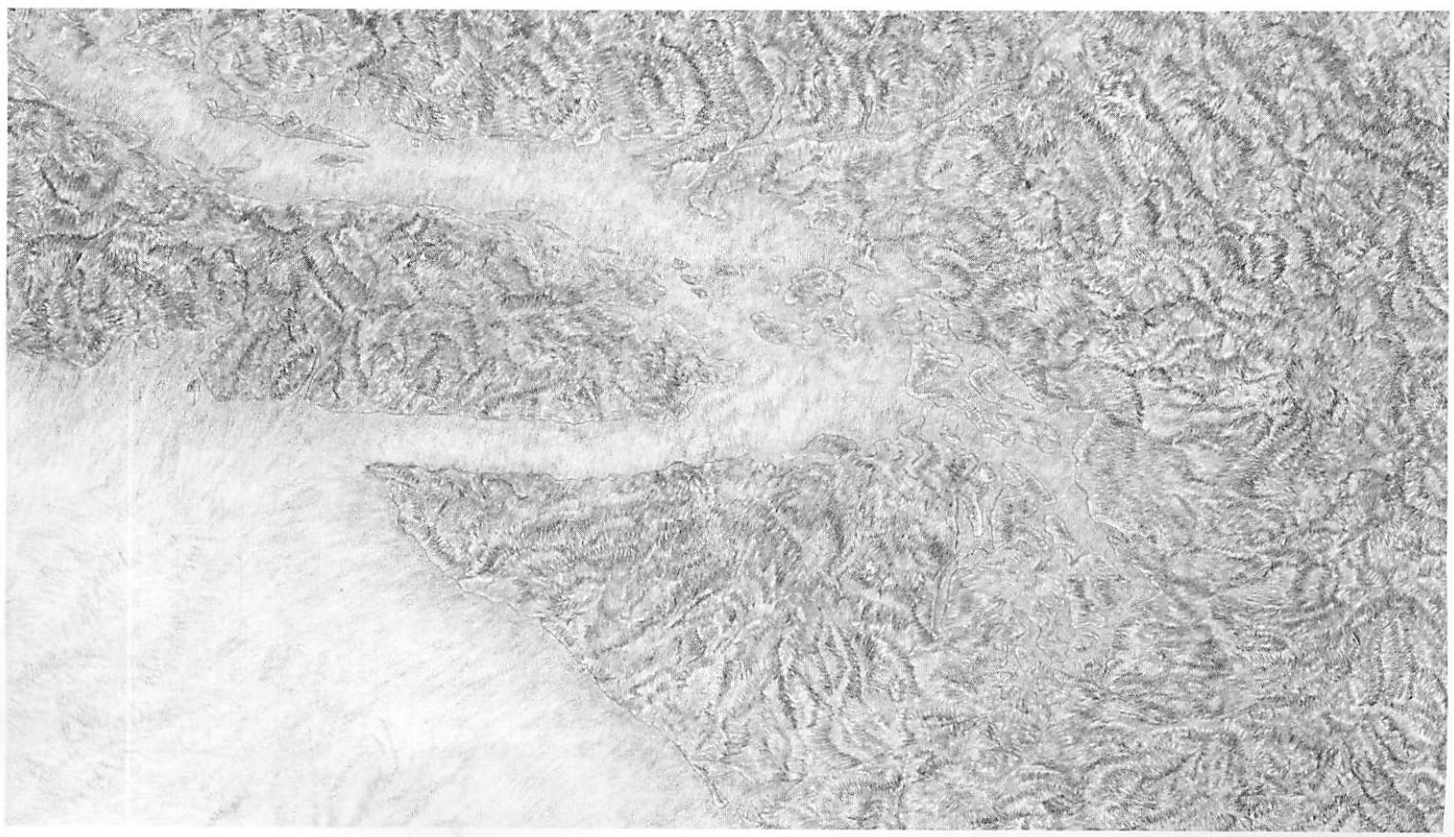
It was an auspicious beginning for the series and it evoked this observation by Jay Becker, publisher of the *Vashon Island Beachcomber:* "Had this kind of series been available in time for eastern estuaries it might have saved Chesapeake Bay, for example, for food, frolic and industrial uses at the same time instead of one use tending always to exclude others."

In the next book, *Governing Puget Sound,* author Robert L. Bish provided readers with a lucid description of the legal and institutional framework within which decisions on the uses of the Sound's resources occur. His incisive analysis of that framework traced the roots of regional govenance to English common law and then placed it within the context of American federalism. Because it is one of a very few volumes addressing regional government, Bish's book finds its way into classrooms throughout Washington and in other states as well.

Volume three was published in November 1982. *Marine Birds and Mammals of Puget Sound* by Tony Angell and Kenneth C. Balcomb, III, described the forces affecting populations of these creatures and provided detailed descriptions and illustrations of marine birds and mammals by families. Primarily, because of Angell's graceful and meticulous drawings, this proved to be a popular volume. By 1984, the first 5,000 volumes were sold and the book was reprinted. But sales were not the only measure of success. In 1983, the prestigious Rounce and Coffin Club chose the book for inclusion in its annual exhibition of outstanding books published in the Western United States. That same year, Bookbuilders West awarded the book not only a certificate of merit and a "Judge's choice" in the highly competive trade book category, but the judges also described it as "perhaps the best book in the whole show . . . a wonderfully skillful and inspired marriage of typography, illustration, cartography, and diagrams—all superbly handled with only one color."

With the Spring of 1983 came two further volumes: *The Fertile Fjord: Plankton in Puget Sound* by Richard M. Strickland and *The Coast of Puget*

Illustration of Puget Sound by Constance Bollen. From The Shape and Form of Puget Sound *by Robert Burns. Published by the Washington Sea Grant Program and available from bookstores or the University of Washington Press, Seattle.*



Publications

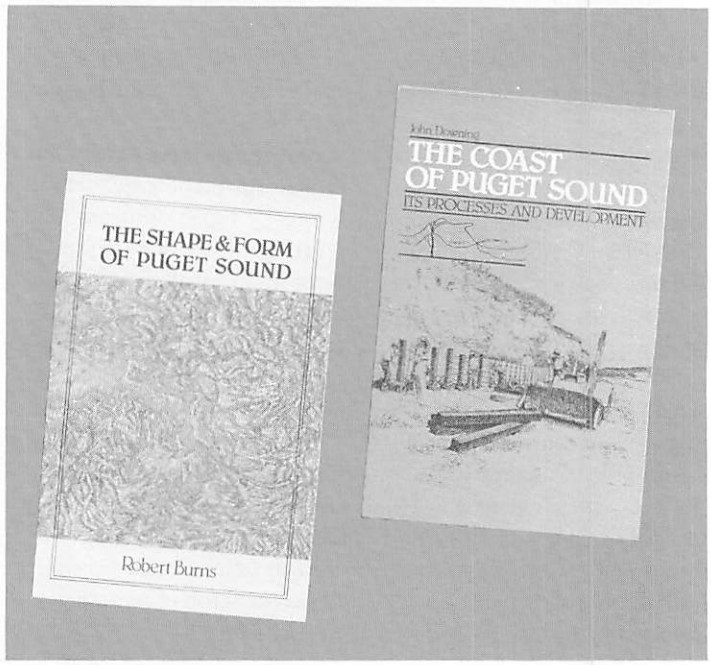
Sound: Its Processes and Development by John Downing. In the former, author Strickland describes the enormous variety of phytoplankton and zooplankton, and explains their importance as sources of food, oxygen, and energy; as ecological and paleontological indicators; and even as early warning systems for poisons in the marine environment. Copious illustrations and exhaustive references reinforce the scientific authenticity of the book, yet it is not a dull, academic tome. It is instead, an engrossing and provocative treatment that generates a real appreciation for all forms of plankton and their interactions within estuaries.

In his book on coastal processes and development, author Downing describes the glacial legacies that laid the foundation for the shores, cliffs, rivers, lakes, basins, and sediment compositon of the Puget Sound region. He explains in detail the physical factors that maintain or alter nearshore areas—waves and currents, sediment transport and erosion, storms and wind patterns. He also addresses natural and manmade hazards, in particular oil spills. Like the other volumes, the book is a must for all those who use or care about Puget Sound and wish to understand its past, present, and future.

Volume six, *The Shape and Form of Puget Sound* by Robert Burns, tells the story of the origin of Puget Sound and the processes that have shaped it. Burns's account progresses, layer by layer, from the grand scale of the formation of the American Cordillera—the mountainous western edge of the Americas—through periods of glacial scouring, and finally to the fine-scaled weathering processes that have changed the Northwestern landscape within human memory. Into his geological history, Burns weaves the insights provided by the new understanding of continental drift and plate tectonics. This is the first regional geology to take these theories into account.

However, the story of Puget Sound's books is still in the making. In final production is an account by Daniel Cheney and Thomas Mumford, Jr. of the region's shellfish and seaweed harvests. On the editors' desks are manuscripts written by Ernest Salo and Steve Ralph on Puget Sound fishes and by Alyn Duxbury and Eugene Collias on the properties of Puget Sound waters. As with the earlier volumes, the planned ones are expected to be used in college classes, read by professionals who help manage the Sound, and become initial background for interested laymen.

All in all, the collaboration of University scientists, scholars, writers, editors, artists and publishers made possible by Sea Grant has this payoff for the citizens of Washington State: Sound information!



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The following books published by the Washington Sea Grant Program may be ordered through your local bookseller or from the University of Washington Press, Seattle, WA 98195. Please cite the International Standard Book Number (ISBN) when ordering. If ordering directly from the Press, please make checks payable to the University of Washington Press. Remittance must accompany orders from individuals. U.S. currency only. Washington State residents please add applicable sales tax. Minimum order is $10.00. Please add $1.75 postage and handling.

Robert Burns. 1985. *The Shape and Form of Puget Sound.* ISBN 0-295-96184-8. $8.95.

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McKernan Lectures in Marine Affairs

These lectures may be ordered from Washington Sea Grant Communications, University of Washington, 3716 Brooklyn Avenue N.E., Seattle, WA 98105. Checks should be payable to the University of Washington. Remittance should accompany orders from individuals. U.S. currency only. Washington State residents, please add applicable sales tax.

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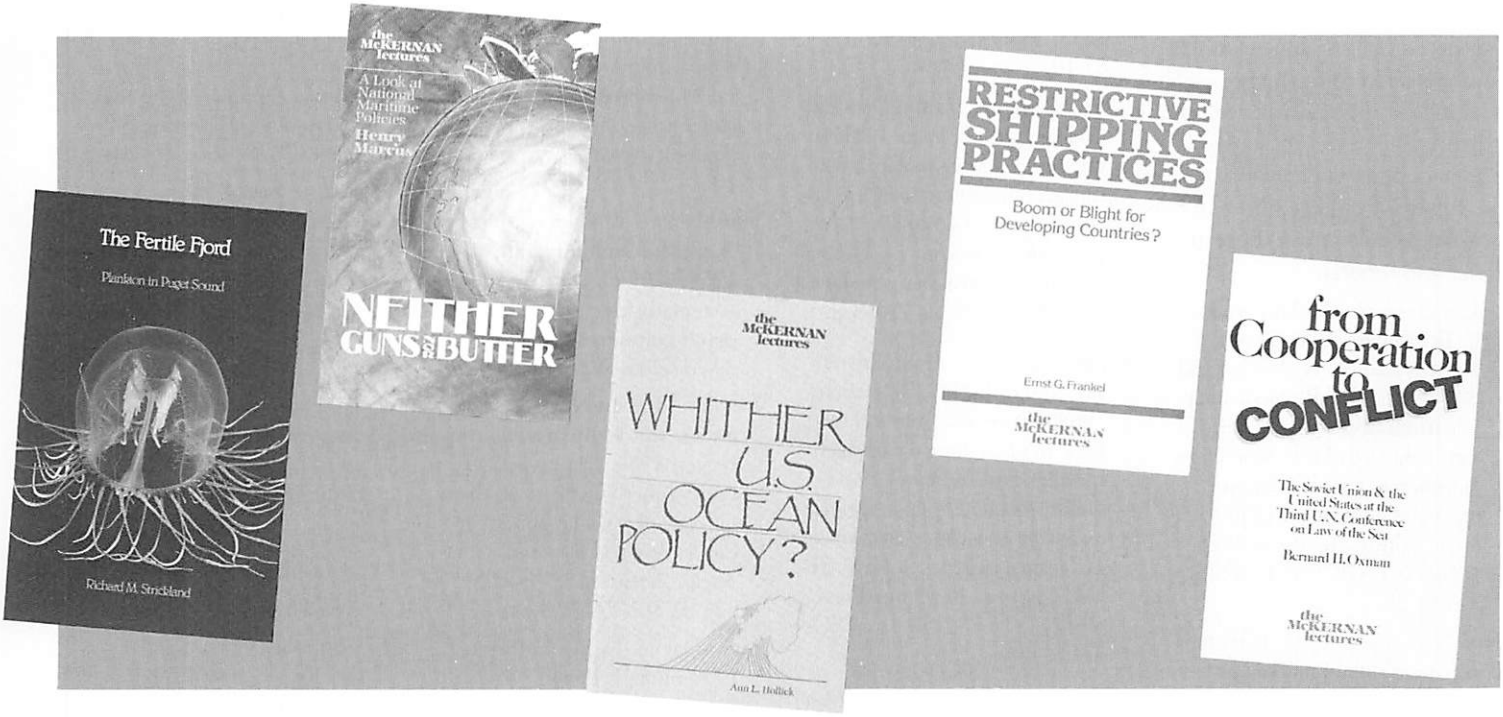

Advisory Publications

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These proceedings may be ordered from Washington Sea Grant Communications, University of Washington, 3716 Brooklyn Avenue N.E., Seattle, WA 98105. Checks should be payable to the University of Washington. Remittance should accompany orders from individuals. U.S. currency only. Washington State residents, please add applicable sales tax.

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Wade, Susan O'Malley. 1984. A proposal to amend the Fishery Conservation and Management Act of 1976: At Section 3(14) and at Title 1, Sec. 103 to include tuna in United States fishery jurisdiction. M.M.A. Thesis. UWASH, Institute for Marine Studies. WSG-TH 84-4.

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Walter, Mary Ann. 1984. A genetic and physiologic approach to the characterization of the PJMI virulence plasmid, a mediator of iron sequestration in *Vibrio anguillarum* 775. Ph.D. Dissertation. Oregon Health Sciences University, School of Medicine. WSG-TH 84-14.

PROJECT STATUS & PROGRAM BUDGET

1983 & 1984

Program Area	Year Beginning 1/01/83	1/01/84
RESEARCH AND DEVELOPMENT		
Coastal Resources		
Puget Sound's Maritime Industries - *Robert F. Goodwin* (R/CZ-17)	New	Completed
Regional Seaport Institutions - *David J. Olson* (R/CZ-15)	Continuing	Completed
Laws Affecting Port Expansion in Washington State - *Marc J. Hershman* (R/CZ-18)	New	Completed
Coastal Resource Governance - *Robert L. Bish* (R/CZ-16)	Continuing	Completed
Maritime Week and Conference - *Marc J. Hershman* (R/CZ-19)	——	New/Completed
Fisheries		
Biotelemetry Investigations of Harbor Seals - *Allan T. Scholz* (R/M-1)	New	Completed
Acoustic Estimation of Salmon in Terminal Areas - *Ole A. Mathisen* (R/Ac-8)	Continuing	Completed
Herring Egg and Larval Survival - *Bruce S. Miller* (R/F-50)	New	Continuing
Modeling the Dynamics and Management of Clam Stocks - *Vincent F. Gallucci* (R/F-38)	Continuing	Completed
Oyster Drill Bioassay Development - *Kenneth K. Chew* (R/F-45)	Continuing	Completed
Estuarine Carrying Capacity of Juvenile Chum and Pink Salmon - *Robert C. Wissmar* (R/F-47)	New	Completed
Dungeness Crab Studies - *David A. Armstrong* (R/F-49)	New	Completed
Demography of Intertidal Predators of Clams - *Vincent F. Gallucci* (R/F-52)	New	Completed
Baitfisheries Oceanography - *T. Saunders English/Bruce Frost* (R/FO-1)	——	New/Completed
Puget Sound Dungeness Crab Habitat - *David A. Armstrong* (R/F-54)	——	New
Physical Structure, Plankton, and Larval Fish Interactions - *Michael R. Landry* (R/FO-2)	——	New
Aquaculture		
Finfish		
Effects of Diet, Size and Time of Release on Salmon Returns - *Ernest L. Brannon* (R/A-38)	New	Completed
Coho Salmon Stock Development for Pen Culture - *William K. Hershberger* (R/A-15)	Continuing	Completed
Induced Polyploidy and Gynogenesis in Pacific Salmon - *William K. Hershberger/Fred M. Utter/ Gary H. Thorgaard* (R/A-31)	New	Continuing
Temperature Control in Salmon Culture - *Ernest O. Salo* (R/A-35)	New	Completed
Improving Coho Survival Through Exercise - *Lynwood S. Smith* (R/A-28)	Continuing	Completed
Salmon Broodstock Diet Development - *Ronald W. Hardy* (R/A-27)	Continuing	Completed
Endocrine Control in Salmonids - *Walton W. Dickhoff* (R/A-18)	Continuing	Completed
Molecular Studies of Bacterial Fish Diseases - *Jorge H. Crosa* (R/A-20)	Continuing	Continuing
Size-Dependent Mortality of Salmon - *Stephen B. Mathews* (R/A-34)	New	Completed
Computerized Forecasting in Salmon Hatcheries - *George W. Klontz* (R/A-30)	New	Continuing
Salmonid Reproduction Symposium - *William R. Davis/Louie S. Echols* (R/A-36)	New	Completed
Smolt Release Strategies - *Robert L. Burgner* (R/A-37)	New	Completed
Induced Polyploidy and Gynogenesis in Pacific Oysters - *William K. Hershberger* (R/A-39)	——	New/Completed
Using Hydroacoustics to Protect Cultured Mussels from Ducks - *Kenneth K. Chew* (R/F-51)	Completed	——

Program Area	Year Beginning 1/01/83	1/01/84
Shellfish		
Oyster Hatchery and Genetic Study - *Kenneth K. Chew* (R/A-10)	Continuing	Completed
Molluscan Culture Studies - *Kenneth K. Chew* (R/A-16)	Continuing	Completed
Parasite Control of Paralytic Shellfish Poisoning - *Kenneth K. Chew* (R/A-33)	New	Completed
PSP: Analytical and Biochemical Investigations - *Wayne B. Iwaoka/ John Liston* (R/A-32)	New	Completed
Seaweed		
Seaweed Aquaculture - *J. Robert Waaland* (R/A-11)	Continuing	Completed
Marine Studies		
An Economic Study of the Washington Commercial Geoduck Fishery - *Robert Stokes* (R/MS-21)	——	New/Completed
An Economic Investigation of Fisheries Regulation - *Jonathon M. Karpoff* (R/F-53)	——	New
Marine Product Development		
Crab Shell Chitosan as a Commercial Fungicide - *Lee A. Hadwiger* (R/X-10)	Continuing	Completed
Commercialization of Chitin Production - *G. Graham Allan* (R/X-12)	New	Completed
Determinants of Flesh Texture in Stored Fish - *John Liston* (R/F-48)	——	New
Ocean Engineering		
Marine Acoustics Program - *Richard E. Thorne/ John Ehrenberg/Edward O. Belcher* (R/Ac-11)	Continuing	Completed
Dynamic Response of Fishing Vessels - *Bruce H. Adee* (R/E-10)	New	Completed
Long-Term Ocean Bottom Observatory—Prototype Vent Monitor - *John R. Delaney* (R/E-11)	——	New
Seamount and Ocean Ridge Circulation Study - *Thomas B. Sanford* (R/E-13)	——	New
Collection and Characterization of Biofouling Marine Caulobacters - *Nina Agabian* (R/C-1)	——	New/Completed
Effects of Variations in Mixing on the Circulation in Estuaries - *Maurice Rattray, Jr.* (R/NE-14)	——	New
EDUCATION AND TRAINING		
Education/University		
Extended Fisheries Training - *Douglas G. Chapman* (E/F-4)	Continuing	Completed
Donald L. McKernan Lectures in Marine Affairs - *Edward L. Miles* (E/MS-7)	Continuing	Continuing
Diagnostic Pathology Training - *Marsha L. Landolt* (E/F-5)	Continuing	Completed
Our Ocean Heritage—Course Development - *Dean A. McManus* (E/O-1)	——	New
Education/Other Institutions		
Grays Harbor College Pen-Rearing Project - *John M. Smith* (T/F-4)	New	Completed
Marine Education Dissemination - *Andrea Marrett* (E/T-1)	Continuing	Completed
Education/Interns		
Sea Grant Internships - *Louie S. Echols* (E/I-1)	Continuing	Continuing

Program Area	Year Beginning 1/01/83	1/01/84
ADVISORY SERVICES		
Marine Advisory Services		
Washington (and Columbia) Marine Advisory Services - *Robert E. Harris* (A/FP-7)	Continuing	Continuing
Program Communications		
Washington Sea Grant Communications Program - *Patricia Peyton* A/PC-5	Continuing	Continuing
Puget Sound Publication Series - *Patricia Peyton/Alyn C. Duxbury* (A/PC-7)	Continuing	Continuing
Office of Applied Marine Economics		
Applied Marine Economics - *James N. Bray* (A/Ec-1)	Continuing	Completed
MANAGEMENT		
Management of the Washington Sea Grant Program (Administration) - *William R. Davis* then *Louie S. Echols* (M-1)	Continuing	Continuing
Management of the Washington Sea Grant Program (Rapid Response Fund) - *William R. Davis* then *Louie S. Echols* (M-2)	Continuing	Continuing

PROGRAM BUDGET

	1983		1984	
	Sea Grant	Matching	Sea Grant	Matching
Coastal Resources	133,400	67,400	115,600	56,700
Fisheries	207,100	139,700	185,400	86,200
Aquaculture	595,300	333,200	565,900	315,900
Marine Products	75,000	27,600	109,900	41,300
Ocean Engineering	180,600	43,900	199,500	45,800
Research and Development	**1,191,400**	**611,800**	**1,176,300**	**545,900**
Education/University	24,500	19,000	25,400	20,200
Education/Other Institutions	43,500	48,600	57,800	55,900
Education/Internships	84,000	1,400	30,000	1,000
Education and Training	**152,000**	**69,000**	**113,200**	**77,100**
Field Advisory Services	555,400	279,800	584,200	294,800
Program Communications	218,200	11,400	221,000	12,200
Advisory Services	**773,600**	**291,200**	**805,200**	**307,000**
Rapid Response/New Development	**117,700**	**19,400**	**88,600**	**19,700**
Program Management	**125,700**	**207,400**	**127,600**	**220,600**
Total	**2,360,400**	**1,198,800**	**2,310,900**	**1,170,300**

This summary is only aproximate. The official financial report will be submitted to the Office of Sea Grant Programs, National Oceanic and Atmospheric Administration, in accordance with the federal grant requirements.

COMMITTEES '83-'84

PROGRAM AREA COORDINATORS

Research and Development

Coastal Resources
Marc J. Hershman

Fisheries Management
Roy E. Nakatani

Aquaculture
Roy E. Nakatani

Marine Products
G. Graham Allan

Ocean Engineering
Bruce H. Adee

Education and Training

University of Washington
Louie S. Echols

Other Institutions
Alyn C. Duxbury

Marine Advisory Services
Robert E. Harris

Communications
Patricia A. Peyton

ADVISORY COUNCIL SEA GRANT MARINE ADVISORY SERVICES

Desmond P. McArdle
Bellingham Vo-Tech Institute

Thomas R. Quann
Washington State University

Donald W. Smith
Marine Technology Branch
Seattle Community College

James C. Barron
Washington State University

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Washington Sea Grant Program
University of Washington

Aquaculture
Douglas G. Chapman, Director
Center for Quantitative Sciences
University of Washington

Conrad V. W. Mahnken
Northwest & Alaska Fisheries Center
National Marine Fisheries Service

Charles Woelke
Washington Department of Fisheries

At Large
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Applied Physics Laboratory
University of Washington

Education
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College of Education
University of Washington

John C. Serwold, Professor
Science Division
Shoreline Community College

Fisheries
Lee Alverson, Managing Partner
Natural Resources Consultants
Seattle, WA

Sig Jaeger
North Pacific Fisheries Development, Inc.

Marine Ecology
Karl Banse, Professor
School of Oceanography
University of Washington

Joan Thomas, Regional Manager
Northwest Office
Washington Department of Ecology

Ocean Engineering
Robert Francois, Head
Arctic and Ranges Department
Applied Physics Laboratory
University of Washington

Neil M. Hawkins, Chairman
Department of Civil Engineering
College of Engineering
University of Washington

Marine Policy
James A. Crutchfield, Professor
Emeritus
Institute for Marine Studies

University of Washington
John DeMeyer, Manager
Division of Marine Land Management
Washington Department of Natural Resources

Ex Officio
D. James Baker, Jr., Dean 1983
Norbert Untersteiner, Dean 1983-84
G. Ross Heath, Dean 1984-
College of Ocean & Fishery Sciences
University of Washington

Washington Sea Grant Program
College of Ocean & Fishery Sciences
University of Washington
3716 Brooklyn Avenue N.E.
Seattle, WA 98105

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