California Ocean Research

A Sea Grant Sampler

Introduction

There are great and ever-growing funds of scientific and technical knowledge and understanding of humankind and the planet. One of the most active is the understanding of the sea, of human influence upon it, and of opportunities for human betterment from its resources.

Knowledge and understanding of the oceans encompass the span between the broadly fundamental and the sharply practical. This wide range of knowledge of the sea clearly possesses great potential for important guidance of the directions of human activities. Yet its influence has been less than its potential. Most legislative and regulatory actions have been little influenced by what is known about the sea and reflect a failure of the research scientist, the public and those in industry and government to communicate.

This failure of communication between the scientist and the public is not restricted to marine science, of course, but is common in many fields. It thus becomes vital to develop insight into the complexities of this fundamental and general problem of our times, to engage in thoughtfully designed experiments, and to encourage and nurture ideas that may grow into meaningful bridges of communication across the gulf that now cleaves action from understanding.

The Sea Grant Program has approached the problem of bridging this gulf in a number of ways. The Marine Advisory Program disseminates information on marine-related matters, and undertakes to advise on specific problems. Sea Grant-funded marine education projects attempt to inform children who may become decision makers in the future. The conventional lines of graduate student support and scientific publication remain, of course, important.

The "Sea Grant Sampler" is a long-term experiment, an involvement of bright young science-writing students in the task of penetrating and explaining the aims, aspirations, and significance of a number of practically oriented research programs. By involvement of this sort there may develop an increasing cadre of those competent to strengthen the bridges of communication linking understanding and action.

To develop the ocean's resources wisely, scientists and non-scientists alike must understand the potential of the ocean and the implications of developing that potential. This booklet is intended to educate and interest people in current ocean research.

Professor John D. Isaacs
Director, Institute of Marine Resources

COASTAL ZONE MANAGEMENT—
Crossing the Boundaries

California's coastal zone management problems cut across boundaries between legal, social, economic, and scientific concerns. Coastal developments—residences, industries, power plants, and harbors—have degraded scenic and recreational areas and disrupted sensitive natural systems. Efforts to conserve and protect coastal resources have brought regulatory agencies into conflict with landowners and businesses seeking to develop their coastal property.

California's coastal zone is now governed by the California Coastal Act of 1976, a far-reaching law designed to "protect, maintain . . . enhance and restore" California's natural and man-made coastal resources. The Act created the California Coastal Commission and required that the governments of the forty-six cities, fifteen counties, and four port districts along the coast draft and implement local coastal programs consistent with the provisions of the Act.

The so-called Coastal Act requires local governments to grant permits to coast-dependent development that minimizes the disturbance of sensitive coastal ecosystems and the alteration of natural landforms. The Act created an urgent need for information about the biological and geological processes of the coastal zone. Three Sea Grant-funded research projects are among the many new efforts aimed at supplying the scientific information required for coastal resource management in general, and preparation of local programs in particular.

Sensitive Natural Systems?

California's coastal wetlands are important natural habitats. More than a million migrating waterfowl visit the wetlands each year. Five endangered species—the least tern, the clapper rail, the savanna sparrow, and two kinds of small rodent—exist only in California's coastal wetland habitats. Researchers estimate that development of California's coast has reduced the total wetland and estuary area by 67 percent—from about 381,000 acres at the turn of the century, to a total of 125,000 acres now.

Drs. Robert Holmes and Chris Onuf, biologists at the University of California, Santa Barbara, are studying southern California estuaries. Holmes says, "We're looking at an environment which is really very rare in our part of the world. That in itself makes it worth investigating. Estuaries may change very rapidly, so we feel very strongly as biologists that we'd like to understand them as they are at present." Holmes and Onuf suggest that many wetlands, even if completely protected from human disturbance, will undergo progressive change.

Coastal wetlands are highly resilient ecosystems. They are tolerant of wide

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natural fluctuations in temperature, salinity, and oxygenation—conditions that vary daily, seasonally, and over longer periods of time. The Coastal Act identifies wetlands and estuaries as "sensitive natural resource areas." Holmes and Onuf explain that wetlands are indeed sensitive to certain kinds of disturbances.

Holmes and Onuf say one source of disturbance is the deposition of sediment carried by freshwater streams flowing into the estuaries. Upstream construction, flood control, and water diversion can greatly increase or decrease the flow of water and the accumulation of sediment in estuaries, but the consequent ecological effects are poorly understood. Too little is known about natural sedimentation rates in California estuaries. In response to this lack of basic understanding, a research project has been initiated at Elkhorn Slough in Monterey County.

Holmes and Onuf suggest that the daily tidal flushing of wetlands is adequate to remove much of the gradually supplied sediment, but that major sedimentation effects are episodic, that is, in very wet years, large amounts of sediment can accumulate in very short periods of time. "In one storm period in 1862, a Santa Barbara estuary, which had been until then a navigable waterway, sedimented in—BANG—all at once," says Holmes.

Sedimentation is considered just one of many possibly damaging human effects on wetlands. Drs. Joy Zedler and David Mauriello, biologists at San Diego State University who are studying southern California wetlands, agree with Holmes' and Onuf's estimation of the sensitivity of wetlands. Zedler says, "Estuaries are sensitive to some effects and not others. I had one student who did his master's thesis on trampling to see what visitor use would do. He found differential sensitivity depending on the season. He went into a Salicornia pickleweed marsh and found that in the springtime, during its rapid growth phase, it was highly sensitive to trampling. He did this study a couple of years ago, and none of the areas have recovered yet."

Zedler says that the availability of nitrogen also limits salt marsh plant growth. She explains that in some areas the plants grow more vigorously after fertilization with nitrogen, demonstrating that "ordinarily they're not producing at their maximum." Nitrogen can cause algal blooms in closed lagoons. Zedler suggests that marshes may function as "nutrient traps" which remove nitrogen from incoming water. The estuary ecosystem may respond to the increase in nitrogen by increasing its overall plant productivity while maintaining its ecological balance.

The amount of organic matter produced in an estuary, its "productivity," concerns scientists and coastal managers. They use plant productivity as a gauge of a wetland ecosystem's ability to support both plant and animal life. Researchers have found that some salt marshes on the east coast of the United States are among the most productive ecosystems in the world. In his book, *The Fundamentals of Ecology*, Eugene P. Odum says, "Characteristically, estuaries tend to be more productive than either the sea on one side or the freshwater drainage on the other." Until recently, west coast legislators and conservationists have used east coast productivity data to justify protection of coastal wetlands, citing the lack of adequate ecological research on west coast wetlands.

West coast scientists have hesitated to equate the wetland ecosystems of different coasts. Says Zedler, "The first suggestion, particularly by lawmakers, was that we should preserve west coast wetlands because east coast wetlands have been found to be very productive and very valuable. We expected that our wetlands would not be as productive. But using the same methods as on the east coast, we've shown that, though the vascular plant productivity is not as high, the algal productivity is much higher. The total productivity comes out about the same. Green and blue-green algal mats are the important producers."

East coast estuaries are also valued as productive fish-spawning areas. Some scientists have estimated that estuary-spawned fish constitute as much as 60 percent of coastal commercial fish populations. "You do find commercially valuable species of fish in southern California estuaries," says Holmes, "but in our study area, Mugu Lagoon, their numbers are small." Holmes, Onuf, and Zedler doubt that the estuaries they are studying contribute greatly to valuable fish populations. The relatively small wetland area, and the tendency of the wetland entrances to close, limit southern California estuary's contributions to offshore waters.

Both estuary plant productivity and diversity change when wave-carried sand closes the estuary entrances. Some scientists blame highway and railroad fill structures for reducing the scouring action of the tides in many California estuaries by constricting the estuary openings. "I don't think the estuaries were blocked as often when they were undisturbed," says Zedler. Only exceptional wave conditions or huge stream runoff will reopen the closed channels.

Scientists are now attempting to restore disturbed wetlands by opening closed entrances and by replanting lost plant species. Zedler explains, "The restoration efforts won't reproduce conditions exactly as they were 200 years ago. There are too many things we can't control: sedimentation, runoff, nutrients, noise. . . . What we have to do is enhance what we've got. That may mean putting in artificial structures to keep the area flushed, or creating islands to keep dogs from harassing the birds. The object is to allow for a natural variety of habitats and maintain their highest productivity levels."

Rivers of Sand

Another scientist is developing a technique to improve the quality of California estuaries. Dr. Douglas Inman, an oceanographer at Scripps Institution of Oceanography, studies physical processes, such as the motion of waves, wind, and sand, in the coastal zone. He is testing a device that may be used to open and maintain the entrance channel of a San Diego County estuary.

The device, called a "sand-fluidizer," uses pressurized water to suspend and transport sand. A pump forces water through holes along the bottom of a large pipe anchored in the sand at the bottom of the channel, creating a slurry of water and sand. As the flow removes sand from beneath the pipe, more sand collapses into the stream and is carried towards the ocean. Inman's device has successfully cut an 800-foot long channel through the beach berm at a closed lagoon entrance. Future experiments will determine whether the sand-fluidizer can keep pace with the natural accumulation of sand in the entrance channel.

Estuaries are closed by the same forces that build beaches. The slow movement of beach sand, known as "longshore transport," is powered by breaking waves. In California, waves approach the coast at an angle, usually driving sand southward along the shore. Rivers and streams supply the beaches with sand and sediment eroded from inland drainages.

In an article called "The Coastal Challenge," published in *Science*, Inman says, "Streams and rivers are by far the

"Characteristically, estuaries tend to be more productive than either the sea on one side or the freshwater drainage on the other."

most important source of sand for beaches in temperate latitudes." He explains that in southern California, the longshore movement of beach sand is naturally interrupted at certain places by large underwater valleys, called "submarine canyons." The sand flows into heads of deep canyons and is carried away from the shore. Submarine canyons capture most of the sand contributed by rivers along the southern California coast.

A length of coastline exhibiting sand-supplying streams, extensive beaches, and at least one sand-capturing submarine canyon is called a "littoral cell." Inman explains that each of the five littoral cells in southern California "begins with a stretch of rocky coast where the supply of sand is limited. In a down-coast direction, determined by the prevailing waves, the beaches gradually become wider and the coastline straightens where the streams supply a sufficient amount of sand. Submarine canyons terminate the littoral cell by capturing the supply of sand, thus causing the next cell to begin with a rocky coast devoid of beaches."

Inman notes that the alteration of sand supply caused by the damming of rivers, the mining of coastal sediments, and the construction of breakwaters, groins, and jetties has resulted in permanent changes in the configurations of many coasts.

Jetties, groins, and breakwaters can cause the most dramatic and easily documented disturbances. Says Inman, "Any artificial structure that produces a local accretion of sand by interrupting the transport of sand along a coast will cause, at least temporarily, a corresponding local erosion just down the coast. . . ." The result is a "chain reaction"—the erosion caused by one structure requires the construction of another structure to trap sand to halt the erosion, and so on. "However, if additional structures are built, the down-coast erosion becomes more severe with each succeeding structure," forcing the construction of even more protective works, the artificial addition of sand, or both, says Inman.

"It is apparent that man's intervention in the coastal zone has both material and aesthetic connotations," Inman explains. Not only is beach sand a "valuable recreational asset," but it also "serves to protect the coast from the erosive action of waves."

Erosive Forces and Development Pressures

Coastal managers are concerned about the effects of erosion on shoreline developments. Fifty-five percent of California's shoreline is backed by cliffs or bluffs, and much of the valuable bluff-top property is now experiencing intense development pressures.

Traditionally, local planners have based their permit decisions regarding bluff-edge developments on general erosion statistics identifying "average rates of retreat" for long stretches of coast. Gerald Kuhn, a geologist at the Scripps Institution of Oceanography, is working in association with Dr. Francis Shepard, professor emeritus of Scripps Institution, on a study of coastal bluff erosion in north San Diego County. Kuhn calls the often-used rate-of-retreat averages "erroneous and misleading" when they are applied without reference to specific cliff-rock characteristics or to the nature of the erosion.

"I'm convinced that coastal erosion is episodic, site-specific, and often catastrophic at certain, localized areas," says Kuhn.

Kuhn's study identifies the major causes of coastal bluff erosion. In the absence of a buffering beach, waves can directly attack the cliffs. Large storm waves are particularly damaging and cause most of the catastrophic collapses. Storm waves are often accompanied by rain which saturates the topsoil and pours water down the cliff faces, he says. Sea caves penetrating the cliffs may collapse, causing the overlying bluff-faces to slump. Wave action widens fissures in the bedrock along faults and softer rock strata. Wind-carried sand erodes the cliff faces, especially where previous collapse has exposed softer rock. Rodents and dogs burrow in the cliff-tops, initiating erosive water-courses. When shallow-rooted vegetation, such as iceplant, becomes saturated by rain or irrigation, the heavy, wet masses of soil and vegetation slide down the steep slopes.

The natural forces combine with the many forms of human disturbance on the bluff-tops to speed erosion. In a report to San Diego County, Kuhn wrote, "It is apparent that in areas where the bluff is in its natural state, there is less erosion." Says Kuhn of the bluff-top developments in his study area, "The farther back they are from the top of the bluffs, the better." Pipe trenches and human foot-traffic start new rainwater-runoff channels, contributing to the erosive effects.

Kuhn has also documented the long-term coastal changes. He says, "I think the historical aspect of the investigation is the most important. Using plat maps and tax records from the 1880s we can document 800 feet of shoreward erosion in one location. But we have to look farther to find old shoreline alignments, configurations, and relief of the area, because the amount of retreat may be misleading— the area may have been low-lying sand. That's why it's important to search the tax-base and assessment records. There was real estate on the tax rolls that no longer exists."

Kuhn's work is immediately useful to San Diego County planners, and the techniques he employs can be used by other coastal planners trying to understand the effects of erosion on their coasts. Kuhn notes that many coastal cities have maps and tax records dating to the 1800s. "Anybody could do this kind of investigation," he says, "the documentation just takes time."

Legal Challenges

The California Coastal Commission, now enforcing its legislative mandate to protect and preserve coastal resources, exercises control over all coastal development. But many of the landowners in the coastal zone feel that the Coastal Act has devalued their property without compensating them for their losses. They cite the constitutional dictum that states: ". . . nor shall private property be taken for public use without just compensation." In opposition, conservationists point to previous court decisions, such as the 1972 case of Just v. Marinette County, when the Wisconsin Supreme Court declared, "An owner of land has no absolute and unlimited right to change the essential natural character of his land so as to use it for a purpose for which it was unsuited in its natural state. . . ." California courts now face an arduous series of law suits through which they must determine whether the conservation of coastal resources constitutes a "reasonable legislative goal" even when it conflicts with the rights of landowners. Richard Hildreth, professor of law at the University of San Diego School of Law, is exploring these and related legal issues generated by the eroding bluffs in north San Diego County in coordination with the work of Shepard and Kuhn.

As the coastal zone becomes the focus of many intense challenges over the rights of property owners and the legal responsibilities of government agencies, coastal planners must depend increasingly on scientific information about the changing biological, geological, and physical processes in the coastal zone.

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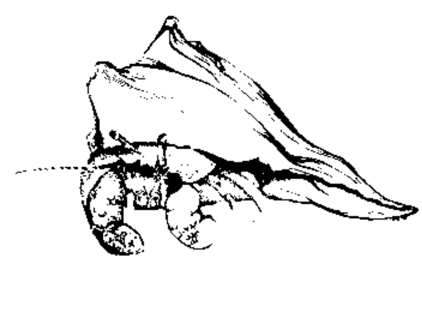

ENERGY RESOURCES—Making the Transition

Long before oil was first refined and used for fuel, Chumash Indians used semisolid petroleum that seeped up along southern California river beds to caulk their seaworthy plank canoes. In the mid-nineteenth century, chemists discovered that the viscous, malodorous liquid seeping up along Pennsylvania rivers could be refined into an excellent lamp oil and lubricant. With the advent of the motor car and increasing industrialization at the turn of the twentieth century, petroleum became the major source of fuel which propelled the U.S. economy to its present energy-intensive, highly technological state.

Heated debates flare over alternative sources of energy as people realize that oil wells will not gush forever. The seemingly endless supply of fuel in the last century has allowed Westerners, particularly Americans, to become energy gluttons who are often unable to see past a fear of shortages in the near future. Such foreshortening provides a two-dimensional view of the issues: the U.S. can either switch to nuclear power or allow the economy to collapse; the U.S. can either switch to solar power or destroy the environment.

When seen in better perspective, energy shortages reflect the old economic principle of supply and demand—shortage occurs when demand exceeds supply. Yet shortages are not simple economic or technical problems. Nor, in the short term, are they problems of geological availability. They are fundamentally political problems. If the flow of foreign oil were cut off by the Organization of Petroleum Exporting Countries, the U.S. economy would be severely disrupted.

We can reduce our demand for foreign fuel by tapping domestic sources—coal and offshore oil—but in the long run this would deplete supply, for those fossil fuels are nonrenewable on the short time-scale. New sources and conservation technologies must be developed.

To make a smooth transition from fossil fuels to renewable sources, a sense of perspective must be maintained—particularly of past experience with depending primarily on a single fuel. Although all people—politicians, city planners, manufacturers, and consumers—must ultimately make tough energy choices, scientists can ease the transition to renewable sources of energy by offering a diversity of alternatives. California Sea Grant researchers may provide some partial solutions by investigating two aspects of the move toward renewable fuels: 1) the development of new technologies, and 2) the most effective use of existing resources.

Energy and Earthquakes

Dr. William Prothero, a geophysicist at the University of California, Santa Barbara, is developing an improved means of assessing the hazard

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earthquakes pose to offshore oil and gas facilities.

Earthquakes cause a wide range of disruptions to humans, from the shattering roll of a magnitude 8.3 on the Richter scale—like the quake San Francisco experienced in 1906—to the minute ripple of a quake with less than one hundred millionth the energy, which most people don't even feel. Understanding the size, motion, and location of quakes and faults gives geologists an idea of what to expect from the dynamics of the earth's crust.

"The determination of seismic risk is basically a puzzle consisting of a wide range of different pieces of information."

Prothero and his associates have improved upon a device, called an Ocean Bottom Seismometer (OBS), that can detect even very small quakes on the ocean bottom. The OBS is dropped to the ocean floor, where it records the relative strength of movements in the earth beneath it.

Prothero's group hopes to use OBSs in an array fifteen to twenty-five kilometers apart in three-month-long deployments. Data from each device will be compared, in an effort to pinpoint the location of quakes, their strength, and possibly the type of motion that occurred.

The seismic mapping of areas under consideration for development may have serious impact on siting and construction criteria of such large facilities as liquid natural gas terminals, nuclear power plants, and supertanker ports. These types of installations are being considered for the Santa Barbara offshore area. By accurately pinpointing even "microearthquakes" in offshore areas of the Santa Barbara Channel and Point Conception, these studies could provide information on the level of seismicity and location of active faults that could be used to guide offshore development.

"The determination of seismic risk is basically a puzzle consisting of a wide range of different pieces of information," says Prothero. "One piece of information is the frequency and motion of large quakes, which don't happen often in a given area. Other pieces are the dates and measurements of various offsets, or movements along faults, in the last hundred thousand or so years. Still another piece is the location and frequency of microearthquakes, which can pinpoint active faults that often go unnoticed in geologic studies, and can point to the location of past large quakes. By putting the information together, we hope to get a picture of where the active faults are. Then maybe we can predict which ones might be active in the future."

Slime in the Cooling System

Drawing oil out of the earth is a troublesome, messy business. Once it is extracted, less than half of the energy it contains can be converted to electricity in a power plant.

Power plants are inefficient energy-converters; they lose up to 70 percent of the thermal energy in a fuel source, dissipating most of this energy as waste heat. Tremendous volumes of ocean or river water are drawn through the cooling systems of power plants to condense steam back into water. Often, slime coats the inside of the cooling-water tubes, reducing the efficiency of heat transfer from steam-containing chambers to cooling waters.

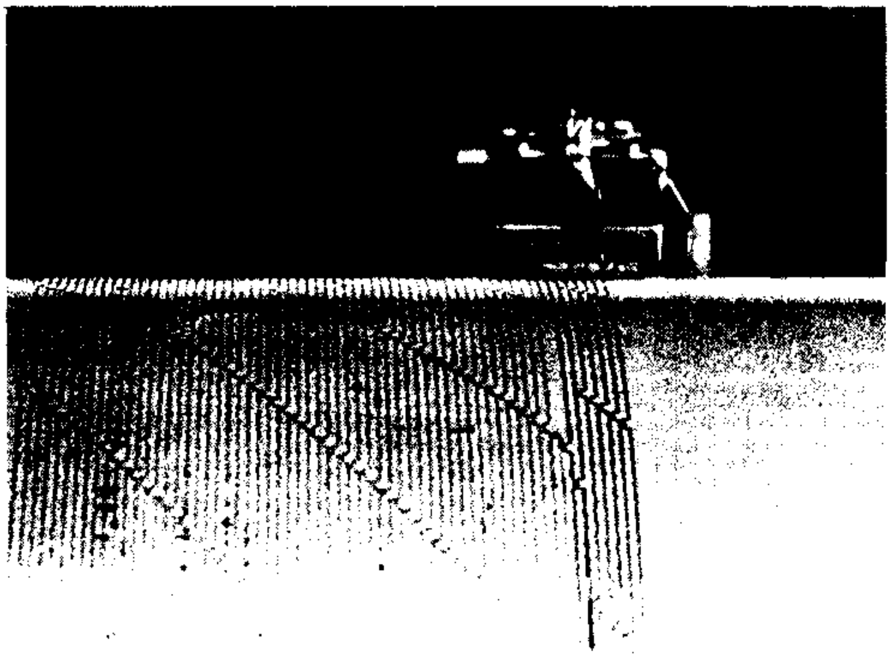
To mitigate this inefficiency, power plant operators pump biocides such as chlorine through the cooling-water tubes, or periodically shut down the heat-exchange system and ram cleaning rods through the pipes to remove the slime. When the cooling water is dumped, particularly in semiclosed systems such as rivers or estuaries, the biocide and toxic heavy metals released by cleaning can reduce biological productivity.

Francisco Vidal, graduate student and Sea Grant trainee at the Scripps

Institution of Oceanography, and his advisors, Professor John D. Isaacs, director of the University of California Institute of Marine Resources, and Scripps bacteriologist Dr. Ken Nealson, are seeking ways to prevent bio-fouling without toxic chemicals.

Two years ago, Vidal and his brother Victor, who is also a graduate student at Scripps, were investigating the physical and chemical properties of underwater hotsprings off Punta Banda, Baja California. To their surprise, although water from the springs was near boiling temperature, they found their water-monitoring instruments were fouled with a thin layer of greenish bacterial slime.

Nealson thought the marine bacteria might somehow be similar to terrestrial forms that inhabit hotsprings like Yellowstone. He says, "By a process of group logic, Francisco, Isaacs, and I figured out there might be those heat-loving, or thermophilic, bacteria in the seawater cooling systems of power plants too."



And so there were. Francisco Vidal collected thermophilic bacteria from both the submarine hotsprings and San Diego Gas & Electric's Encina power plant at Carlsbad, just north of San Diego. He says the bacteria he has successfully isolated and cultured may be a new genera, or at least a marine species of a terrestrial form. Vidal has found that the bacteria form a layer only a few millimeters thick on the inside of the condenser tubes, which nevertheless considerably reduces the flow of heat from the steam-containing chambers to cooling waters. This is the first time marine thermophilic organisms have been isolated and identified as one of the principle factors in the deterioration of heat-exchange efficiency in seawater-cooled condensers.

To find a way to eliminate bacteria from cooling tubes, Vidal hopes to focus on a peculiarity of physiology or metabolism that will indicate the best approach. He may be able to use some of the antibacterial compounds that Dr. William Fenical (see section on New Marine Products) is developing from seaweeds.

Another approach to eliminating the microorganisms is to use bacteriophages, the natural enemies of bacteria, to infect and kill the thermophiles. Vidal hopes to collect and isolate thermophilic phages from the Punta Banda hotsprings. Large doses of phages may prove a particularly efficient way of eliminating bacteria. A constant supply of phages is possible to maintain, for they are relatively easy to grow in a lab; phages themselves would not interfere with heat transfer in the tubes because they disappear once they have killed all the bacteria.

"Anybody can stick a propeller in an ocean current and generate a bit of electricity, but it takes the most sophisticated technology in the world to tap the energy in uranium."

Once Fenical's antibacterial compounds are ready, and if phages have been isolated, Vidal will test their effectiveness on both his lab strains and "wild type" bacteria. He has built a model of a heat-exchange system, through which he can pump warm seawater to encourage spontaneous growth of bacteria. In this way, he can test compounds and phages on wild bacterial strains in a controlled environment.

"These bugs are tolerant of temperatures up to eighty-two degrees centigrade," says Vidal. "Calcium sulphate precipitates out of seawater at that temperature and coats or scales the inside of pipes. Scaling further reduces heat exchange, so it doesn't make sense to kill them with heat. Even chlorination doesn't eliminate them entirely. Using compounds from the ocean is more sound environmentally and may be more effective than using toxic chemicals."

Thermophilic bacteria are just one factor in many that cause power plants to waste much of the potential energy in fuel. Professor Isaacs says, "Interestingly enough, outside of the usual energy forms such as coal and oil, the more concentrated the form of natural energy, the more difficult it is to use. Anybody can stick a propeller in an ocean current and generate a bit of electricity, but it takes the most sophisticated technology in the world to tap the energy in uranium."

Maybe, as Isaacs suggests, it is quite natural that we have trouble converting natural forms of energy into usable energy, for it is as difficult for nature to translate energy from one form to another as it is for us humans. Photosynthesis, which involves a long series of reactions to transform electromagnetic energy in sunshine to chemical energy in starch and sugar, is at least as complex a process as is generating electricity from the chemical energy in petroleum.

Like all forms of energy, except nuclear fission, nuclear fusion, tidal, and geothermal, chemical energy in petroleum originally came from the sun. Trapped and compressed under sedimentary layers eons ago, the solar energy in photosynthesizing plants was transformed into a more concentrated form in fossil fuels.

Where Rivers Flow Into the Sea

Dr. Gerald Wick, research physicist and assistant director of the Institute of Marine Resources, is trying to tap another form of solar energy. When the sun evaporates the ocean and rain replenishes rivers, chemical energy is stored in the difference in salt concentrations, or salinity gradients, between fresh and salt water.

If a closed container contains both water and air, some of the water will vaporize, even at room temperature. Vapor pressure is a measure of the force this water vapor exerts on the walls of the container at a given temperature. If the water is heated, more of it vaporizes, and vapor pressure increases. When vapor pressure equals air pressure, water boils.

The presence of dissolved salt lowers water's vapor pressure, and therefore increases boiling temperature. This means that when fresh water and seawater are heated to the same temperature, at the same air pressure, the fresh water vaporizes faster than the salt water.

Wick hopes to use the difference in vapor pressure between salt and fresh water to generate electricity. He has built a small model of a salinity gradient energy-converter which consists of two vats of water—one salt and one fresh—sealed together by a tube. Wick removes all the air above the vats to create a vacuum and effectively lower the boiling temperature of both vats of water. He then heats both vats to the now-lowered boiling temperature of the fresh water, which is always below that of the salt water. The fresh water gives off vapor that travels along the tube to the salt water to equilibrate the difference in vapor pressure between the two vats. A turbine placed in the tube would be turned by the vapor flowing from the fresh water vat toward the salt. Both vats must be replenished occasionally as the fresh water boils off and the salt water is diluted.

The major source of energy in Wick's converter is the difference in vapor pressure between the two vats, rather than heat. The flow of vapor would occur even at room temperature; heating the vats simply makes the system more efficient by increasing the difference between the salt and fresh water vapor pressures and the rate of vapor flow.

Wick is now in the process of measuring transfer rate, or flow of vapor, and he hopes to design a system that will actually generate power. A salinity gradient energy-converter will be practical only if the net energy converted to electricity is appreciably greater than the energy put into the system to create a vacuum and to heat the vats. Wick says solar energy could be used to heat the water.

Wick says, "Salinity gradients are interesting primarily because they contain the greatest density of energy of all renewable ocean sources. In other words, gram for gram of water, there is more energy available where salt and fresh water mix than in wave power or even ocean thermal gradients." Wick points out that there is constantly renewed energy available where rivers flow into the sea, or into hypersaline sinks, such as the Dead Sea and Great Salt Lake.

"We must look to various renewable sources," says Isaacs. "The industrial revolution was ushered in by machinery that used coal at 3 percent efficiency, and there's a lot more river water running into the seas than there is coal. Even if you use salinity gradients at very low efficiency, you're still gaining."

Salinity gradients, more efficient power plants, safe offshore facilities—these partial solutions may ease the transition from fossil fuels to multiple renewable sources of energy. By maintaining a sense of perspective, the transition can be made without narrowing energy issues into either/or situations.

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FISHERY MANAGEMENT— A Tangle of Questions

The passage of the Fishery Conservation and Management Act of 1976 mandated a change in the perspective of people involved in the regulation of U.S. fisheries. Traditionally, fishery managers tried to protect fish populations from depletion, and at the same time allow fishermen to harvest as many fish as possible under that constraint. The provisions of the Fishery Conservation and Management Act required fishery managers to shift to a broader view—considering the social and economic consequences of management as well as the biological consequences of fishing.

The Act created a 200-mile zone in which the U.S. assumes exclusive management authority over all fish except highly migratory species. The Act also established Regional Fishery Management Councils to prepare management plans for each fishery under U.S. control. According to the Act, each management plan must be designed to allow fishermen to harvest the amount of fish that will provide the "greatest overall benefit" to the United States, especially to the nation's food production and recreational opportunities.

To determine the "greatest overall benefit," a Regional Council must consider not only the effect fishing has on fish populations, but also the effect fishery management has on human populations. How will regulation of a fishery affect sport fishermen and commercial fishermen, processors and consumers? How will limitations on domestic fish catch affect the price of seafood, the employment rate in coastal towns, the fishermen's income?

A Measure of Pleasure

Current research in fishery management reflects the change in the perspective of the managers. Scientists are attempting to gather the data needed to determine the social and economic consequences of management.

Dr. Suzanne Holt, an economist at San Diego State University who is presently a visiting professor at the University of California, Santa Cruz, is attempting to measure an elusive quantity called psychic income—the satisfaction that fishermen get from fishing. In her Sea Grant-funded study of the U.S. Pacific albacore fishery, Holt is examining the nonmonetary reasons that people become fishermen, in an effort to understand how a fisherman's view of his profession affects his behavior.

In most economic analyses of fisheries, the economist assumes that the fisherman is motivated solely by the desire to make a profit. Holt points out problems resulting from this assumption. "Generally speaking, if fishermen were interested in profit exclusively, you wouldn't find them behaving the way they are. Therefore, there must be other kinds of things that interest them—things like pride and independence. . . . There's a

". . . if fishermen were interested in profit exclusively, you wouldn't find them behaving the way they do."

certain kind of pioneer spirit and excitement about fishing still," Holt says. "All these things are lumped together in the category of psychic income." Holt explains that a measure of psychic income seems likely to be a good predictor of fishermen's economic behavior.

How can an economist tell if a person derives psychic income from fishing? Holt offers a simple qualitative answer—"If you offered him a job on shore with the same income, he would turn it down." Holt's research is intended to obtain a more quantitative answer. Using data gathered in interviews with eighty albacore fishermen, Holt will attempt to correlate the size of the income cut that would force a fisherman to switch to another profession with the factors that contribute to his enjoyment of fishing.

"My method is definitely just a rough approximation," Holt maintains. But even a rough approximation is a step toward including human values in the decisions of fishery management.

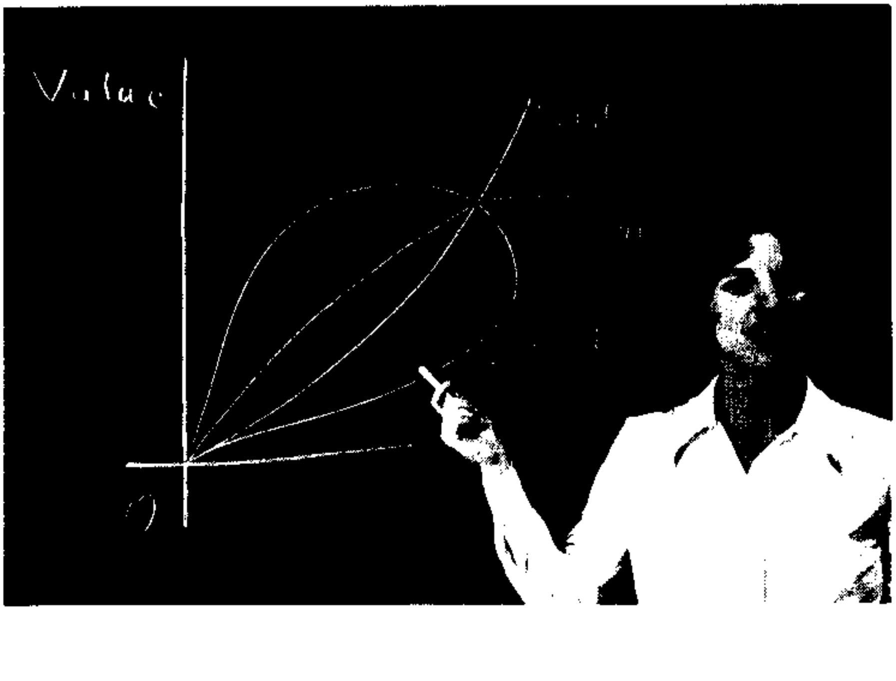
Fish and Politics

The Fishery Conservation and Management Act requires that the kind of information Holt is gathering be considered in management decisions. However, though the Act requires the Councils to consider economic and social objectives in management plans, it does not specify how conflicts between the objectives of different groups involved in a fishery should be resolved. The problems that the Pacific Fishery Management Council encountered in its attempt to establish a management plan for salmon indicate the difficulties of trying to resolve conflicts among user groups.

The salmon fishery is complex—both biologically and politically. Salmon spawn in fresh water, but the young fish return to the ocean and migrate long distances along the North American coast. Most fish return to the stream in which they hatched to spawn; each stream has a separate breeding population. Though these populations mingle in the open ocean, regulations must be designed to manage the population of each stream in order to maintain each of these breeding stocks. Changes in the rivers of the west coast—construction of dams and water diversions, pollution of river water, and destruction of spawning grounds—have interfered with the salmon's upstream migration and spawning. Though hatcheries have been built to compensate for the loss of spawning grounds, salmon populations have declined in many west coast rivers.

Both commercial and sport fishing on salmon have increased in recent years. The west coast populations are harvested by U.S. and Canadian fishermen trolling in the open ocean, by sport fishermen on the ocean and in the rivers, by gill-net fishermen in the rivers of Washington and Oregon, by purse-seine fishermen in Puget Sound, and by several Indian tribes which have been granted certain fishing rights by treaty agreements. Indian fishing rights have been an important management concern since 1974, when a federal court decision recognized that salmon bound for traditional Indian fishing grounds were being intercepted in the open ocean. The court ordered that Indians of certain tribes be allowed to try to catch 50 percent of Washington State's allowable harvest of salmon.

The Pacific Fishery Management Council tried, in its preliminary management plan for salmon, to allow enough fish to escape ocean fishermen to satisfy Indian fishing rights. At the same time, the Council attempted to increase the number of fish that escape all fishermen and reproduce in the Columbia River, an area with a depleted population. To accomplish these goals, the Council increased restrictions on ocean troll fishing—an action that was



not popular with trollers. The Council is presently working on a comprehensive plan for salmon management, but as Council members discovered with their preliminary plan, satisfying all the groups that harvest salmon is likely to prove impossible.

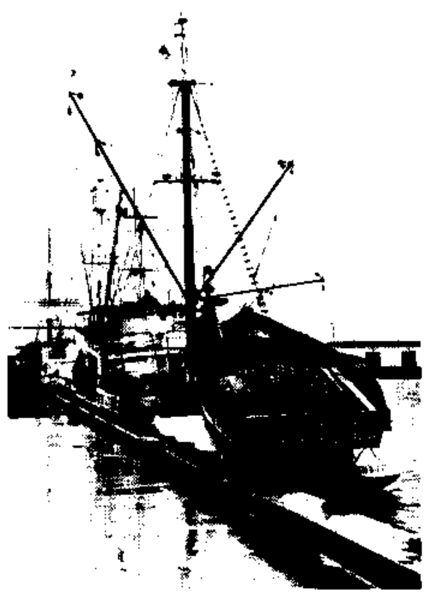
Three political scientists at the University of California, Santa Barbara—Dr. John Moore, Dr. Biliana Cicin-Sain, and Dr. Alan Wyner—are attempting to define the problems of salmon management and to identify possible solutions. The investigation includes surveying the attitudes, interests, and influence of the people affected by management decisions: the fishermen, the processors, the consumers, and the agencies that will implement the plan. To implement the Act as its creators intended, the interests of all these groups must be considered.

Moore emphasizes the necessity for careful consideration of all points of view. "The process by which decisions are made is critically important . . . to assure that the interested parties are represented in proportion to their stake in the outcome."

Patching the Leaky Bucket

Traditionally, the U.S. has managed its fisheries by limiting the fishermen's access to the resource. A fisherman's catch was restricted by shortening the fishing season, by placing areas off-limits, by setting size limits and bag limits, and by allowing the fishermen to use only certain types of gear. Anyone who wanted to fish could compete with all the other fishermen who were trying to harvest the same species.

Economists have pointed out that limiting a fisherman's access to the resource is not the most efficient way to manage a fishery. Some have called the present limited access management system the "leaky bucket" approach, drawing an analogy to a well with a limited inflow of water. The well can



supply a village—as long as less water is drawn from the well than flows in. If the demand for water exceeds the supply, one solution is to punch holes in the bottom of each villager's water bucket in order to limit the amount of water he can draw. The greater the demand for water, the more holes. By limiting access, the government regulates the number of fish caught by punching holes in a fisherman's harvesting technique.

In a study of the California abalone fishery, Moore and his colleagues described two other approaches to management which could be implemented alone or in combination with limited access management: 1) wild populations could be augmented by restocking with young from hatcheries, and 2) regulations could restrict the number of fishermen entering a fishery. In the vocabulary of the "leaky bucket" analogy, limited entry management would reduce the number of buckets in use, rather than punching holes in the bottom of every bucket.

Though limited entry management would restrict the number of boats or fishermen in a fishery, it would not necessarily prevent a fisherman from improving the efficiency of his boat or from getting a larger boat. To adequately protect the resource under limited entry management, the government may also have to control the efficiency and capacity of the fishing fleet. In the vocabulary of the analogy, the government may also have to control the size of the buckets in use.

In the case of abalone, Moore discovered that everyone favored restocking of the wild populations. Limited entry management was not accepted as readily. "Limited entry has been a phrase that automatically evoked a defensive reaction in the minds of fishermen. At the opposite extreme, some resource managers and economists viewed it as a panacea for any fishery," Moore explains. The acceptance of limited entry by some fishermen as a possibility worth considering is very recent. "Limited entry is a policy option that was, in effect, foreclosed, but is now beginning to open up," Moore says. "At least it can be talked about without battle lines being drawn."

In California, limited entry management has been implemented in the abalone fishery. A state law passed in 1976 limits the number of commercial abalone divers by granting diving permits only to those who held a permit the year before, plus a small number of new divers. Since more divers leave the fishery each year than are allowed to enter, the number of divers is reduced each year.

The number of abalones available for harvest has declined drastically during the past decade. Divers cite a variety of reasons for the decline, including poaching, the large number of commercial divers, and the expanding range of the California sea otter, a marine mammal that preys on abalones and other shellfish. Commercial divers and officials of the California Department of Fish and Game also complain about inexperienced divers who pry loose abalones that are below the legal size, measure them, then replace them. Unless the abalone is free of injury from

the prybar, it will almost certainly bleed to death or be eaten by predators.

Limited entry management addresses two of these problems—reducing the number of divers and decreasing pressure on the abalone beds by inexperienced divers.

An Ecological Tangle

In the abalone fishery—as in every other fishery—the problems created by human activities are intertwined with the biology of the oceanic system. The effect of the expanding otter population on the abalone fishery is one thread in a complex web of interactions—the ecology of the California kelp bed.

In the past, management dealt with each species in isolation, ignoring interactions among species. But harvesting abalone affects the animals that compete with abalone and also the animals that prey on abalone. Ideally, to regulate fishing for one species, a fisheries biologist must be aware of the interactions among species and must take into account the effect that pulling one thread is likely to have on the web as a whole.

Californians fish the kelp beds for urchins, abalones, spiny lobsters, crabs, and fish; they harvest the kelp itself for processing into industrial chemicals. In an effort to understand the impact of human activities on the kelp beds, Dr. Mia Tegner, a community ecologist at Scripps Institution of Oceanography, is working with the California Department of Fish and Game on a study of the sea urchin's relationships with other kelp bed organisms and the population dynamics of the sea urchin.

Tegner explains, "For years, we have been fishing individual organisms without regard to the impact of our actions on the community as a whole. . . . In multispecies management, we are trying to look at the ecology of the community as a whole, to work out what the relationships among organisms are, and how one fishery is likely to affect another."

Tegner's research has shown that urchins compete with abalones for space and food: both animals feed on kelp. Where fishing has reduced the abalone population, the urchin population appears to have increased to take advantage of the additional food and space. Human predation has removed another natural check on urchin population growth by reducing the population of two of the urchin's predators—the spiny lobster and a fish called the California sheephead.

When commercial fishing on red sea urchins began seven years ago, some people welcomed the fishery as a way to rid the kelp beds of a pest. "Sea urchins have been sort of the guys in the black hats in the kelp beds," Tegner says. "They were associated with some major declines of kelp beds in the late 50s and 60s." When a sea urchin population grows too large, the supply of drift kelp is no longer sufficient to feed the urchins. When drift kelp is not available, urchins will attack attached kelp plants, severing the plants from their attachement to the bottom. This sort of destructive grazing can be very harmful to the kelp beds.

But Tegner has discovered a relationship that indicates that urchins provide an unexpected benefit for the kelp bed community. Small urchins and juvenile abalones cluster around and under the spine canopy of large red urchins, sharing the drift kelp that the large urchin snares and hiding beneath the spines of the large urchin for protection from predators. Because the sea urchin fishery removes large urchins, the fishery will have an effect not only on the urchin population, but also on the survival rate of small urchins and abalones. Without the protection of the larger urchins, juvenile abalones are more vulnerable to predators. Tegner points out that the protective function of the large urchins is clearly very important to the management of the urchin fishery, yet it is just one species-specific idiosyncrasy. New information about interactions among other kelp bed dwellers may be equally unexpected—and equally important to management.

The Political Web

The web of human interactions affecting fishery management is as complex as the ecology of the kelp bed. In management decisions, policy makers must make an effort to consider economic, social, and biological goals. Unfortunately, reaching all desirable goals is usually impossible.

To minimize waste of labor and capital, for example, a management plan should be designed to allow fishermen to catch the most fish with the least effort. Yet if fish populations are to be protected against overfishing, an increase in each fisherman's ability to fish must be compensated for by a decrease in the number of fishermen. But a decrease in the number of fishermen may mean an increase in unemployment. Two goals—minimizing waste and maximizing employment—seem to be incompatible.

Considering political, economic, social, and ecological data in fishery management is not easy; managers must make choices among conflicting goals. A policy maker in fishery management, like a fisheries biologist, must try to understand the effect of pulling one thread in a complex web.

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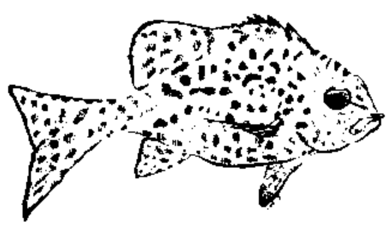

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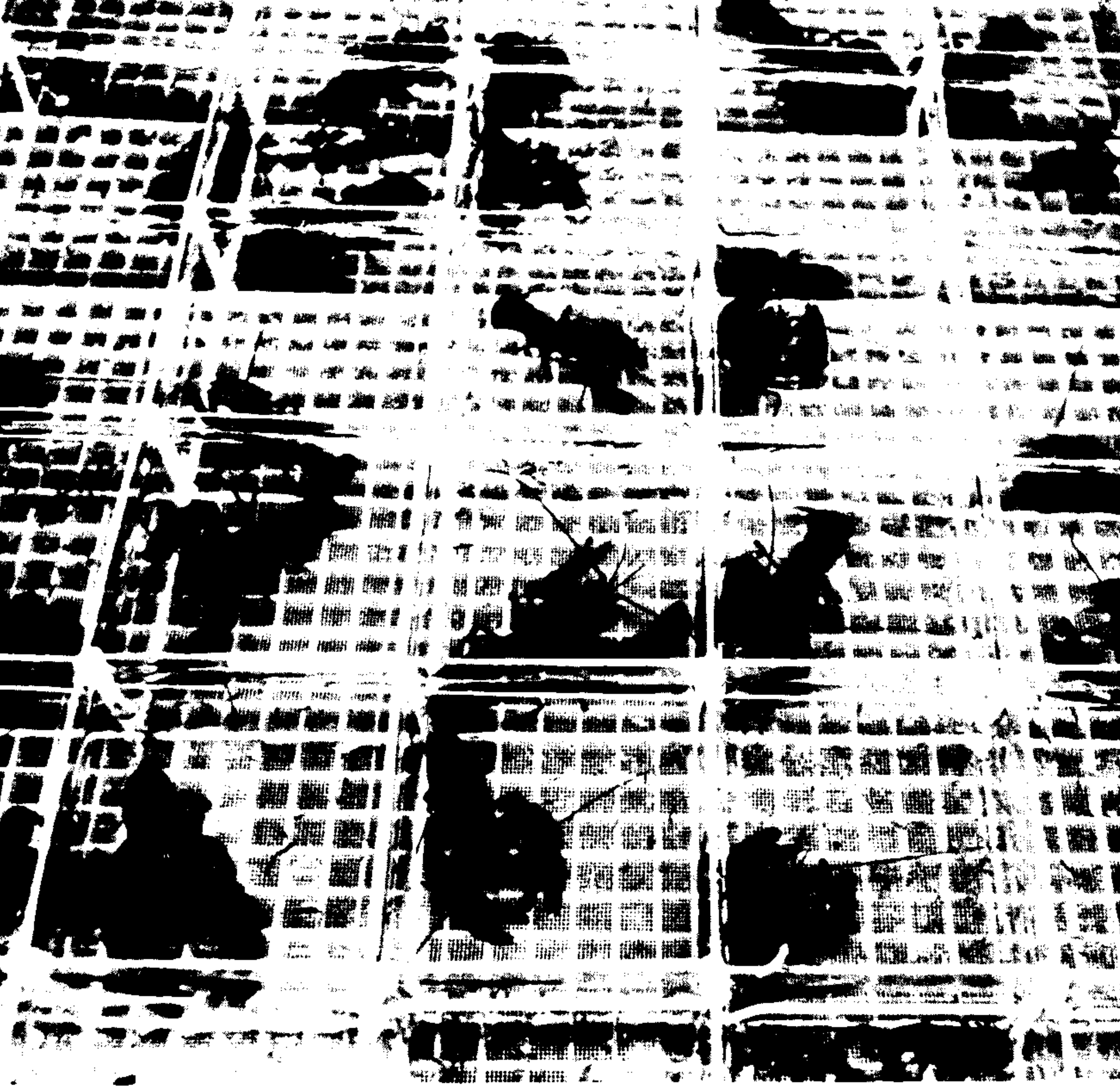

AQUACULTURE— Agriculture Under Water

Tomato plants thriving in sand dunes. Lobsters living in warm water from power plants. And seaweed growing in laboratories. The combinations may sound incongruous, but they are all functional systems devised by Sea Grant researchers to take advantage of the ocean's fertility.

Aquaculture—the cultivation of aquatic plants or animals to produce crops—has a long history. Thousands of years ago, Orientals developed aquaculture techniques in order to breed fish to restock ponds and rivers. The Romans are believed to have grown and harvested fish for their feasts. Some researchers have postulated that California Indians carted trout in watertight baskets to lakes high in the Sierra Nevada Mountains.

In the United States, fish hatcheries were producing young salmon, trout, and shad for restocking fished-out streams and ponds as early as the 1860s. Fish culture, as it was called in the 1800's, was a means of "arresting the gradual extinction of valuable fishes, and restoring our failing and exhausted rivers to their former fruitfulness," according to one author who wrote in 1868.

Primitive and advanced methods of aquaculture—from harvesting fish from a drained pond to sophisticated hatchery techniques—have been developed over the years. Today, oysters, crayfish, salmon, trout, catfish, and other species are successfully farmed in many parts of the country. Scientists are studying the life cycles of scallops, lobsters, algae, abalones, and other species of aquatic life that they believe may also be bred or harvested under controlled conditions.

A Great Potential

Dr. David Leighton and Dr. Charles Phleger, biologists at San Diego State University, are studying the growth and physiology of the purple-hinge rock scallop, *Hinnites multirugosus*, in an effort to develop a culture technology for the species.

Immediately after hatching, rock scallops, like most other mollusks, go through a free-swimming stage. They then settle on available surfaces. At the age of six months, juveniles attach themselves securely to rocks or other surfaces by "cementation"—growth of the shell in close conformity to the rock surface. Leighton has found that after two years the adductor muscle—the edible portion of the scallop—is a good size for eating, about twenty to thirty grams (roughly one ounce).

Because the scallop filters its food, mainly algae, from the water, there is no need to formulate and produce artificial food. Because this scallop can survive a range of depths and temperatures, culture conditions may vary without wiping out the stock. And because female scallops can produce fifty to one hundred million eggs at a time, young larvae are easy to obtain. These reasons, Leighton believes, make the rock scallop

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a good candidate for aquaculture.

Currently, Leighton and Phleger have several culture stations operating in Mission Bay, San Diego, and at offshore locations nearby. The scientists are growing scallops in the different areas to determine what conditions—temperature, depth, salinity, and water quality—give the fastest growth rates.

Leighton is devising a floating lab system where the scallops can be cultured from fertilization through the juvenile stage. The scallops could then be planted in nearby bay and ocean areas to grow to harvest size. This system may provide an economic approach to scallop aquaculture.

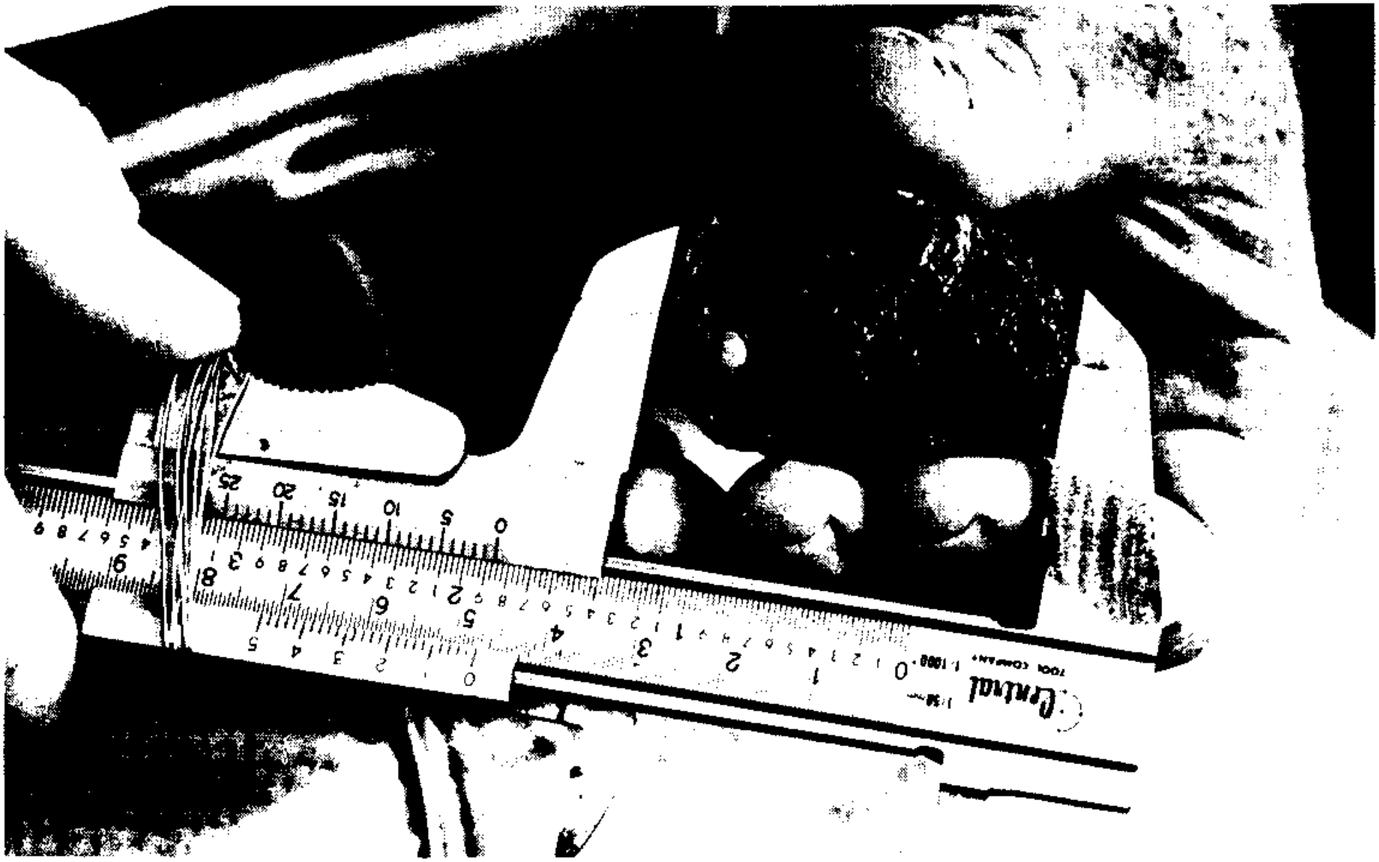
There is a great potential for the rock scallop, according to Leighton. "It may take over where the oyster and the mussel stop," he says. "If we can develop ways to seed public scallop beds in oceans and bays, we may support a new fishery."

The Popular Abalone

Rock scallops are not yet a market item, unlike the popular California abalone. But the abalone population is decreasing. In the wild, abalones take five to seven years to grow to the size at which they can be legally collected. During this period they are preyed on by sea otters, octopuses, and other marine species, and must compete with others for food and secure habitats.

Abalones have been cultivated in protected environments in the open ocean and in tanks in both Japan and the United States. Efforts to culture the abalone have so far proved expensive, partly because of the large mortality of very young abalones.

Dr. Daniel Morse, a geneticist and Associate Director of the Marine Science Institute at the University of California,



Santa Barbara, working with information supplied by Dr. Mia Tegner of the Scripps Institution of Oceanography, has found that juvenile abalones normally settle on rocks covered with a specific kind of red alga. Morse found that the alga will cause young abalones to settle and begin their metamorphosis, developing a hard, protective outer shell.

In a laboratory or culture facility where this alga is not supplied, the young abalone are slow to begin metamorphosis. The abalone are more prone to bacterial infection in their early life stages, so the delay in growth resulting from the absence of the algae may allow a high mortality rate from bacterial infection.

Morse has found the component in the alga which appears to attract settlement of larvae and promote subsequent development. He has been able to supply a chemical, γ amino butyric acid (GABA) which provides an equivalent stimulus. Use of GABA may enhance production by facilitating growth and survival, and may also reduce losses due to infection.

In earlier research, Morse discovered that adding hydrogen peroxide to seawater induces abalones to spawn reliably and controllably. He and his colleagues hope to use the spawning inducer and the development inducer to explore the abalone's natural genetic control of growth and disease resistance.

The East Coast Lobster Comes West

Culture techniques are being developed for another shellfish—*Homarus americanus*, the American or east coast lobster. Researchers at the University of California's Bodega Marine Laboratory have been studying the biology of the lobster since 1971.

Dr. Cadet Hand, project leader for the research says, "We hope that intensive study of this animal by an interdisciplinary team will yield scientific data and a technology that might serve as a general model for aquaculture of other crustaceans."

Five researchers are working with Hand to develop a practical method for aquaculture. They are investigating genetic, economic, nutrition, and disease factors, among others, in order to devise a workable culture system for the lobster. They are also studying other shellfish, including the Dungeness crab.

Geneticists at Bodega are working to develop a good brood stock for *Homarus*. Other researchers at Bodega have developed an economic model for lobster aquaculture which incorporates 120 variables. Others have described, as well as found preventions for, a number of bacterial and fungal diseases.

Perhaps the most difficult problem in lobster culture is finding an inexpensive but nutritionally adequate food. Says Hand, "The dietary requirements for no crustacea are understood. We've had to start from scratch, and we've come a long way in terms of identifying the basic nutritional needs of the lobster." Results from this work may be applicable to shrimp culture.

Other workers are also studying lobster aquaculture. A group from San Diego State University has worked cooperatively with the people at the Bodega Marine Laboratory, sharing information and results. The San Diego researchers are working in aquaculture facilities at two power plants in southern California and at the Scripps Institution of Oceanography. They are taking a new approach toward the breeding and growing of east coast and European lobsters. Mr. Jon Van Olst, Dr. Richard Ford, and Mr. James Carlberg are raising the lobsters in thermal effluent—warm seawater from coastal power plants—to accelerate the growth of the normally slow-growing lobster.

"It takes seven to eight years for a lobster in the North Atlantic to grow to market size," explains Jim Carlberg. "It takes about four years for this growth to

"It takes seven to eight years for a lobster in the North Atlantic to grow to market size. It takes about four years for this growth to occur at ambient Southern California seawater temperatures. But by using warm water, and with the proper rearing conditions, we have done it in two and one-half years."

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Because less time is necessary for lobsters to grow to full size when they are cultivated in warm water, it costs less to produce them. But if the seawater had to be heated, the cost savings from this quick-growth method would be swallowed up by the fuel costs. Using thermal effluent instead of heating ambient saltwater reduces the cost of lobster production by 50 percent.

Coastal power plants use vast quantities of seawater—hundreds of thousands of gallons per minute—to condense the steam which has been used to turn the turbines. This process enables the fresh water to be recycled, but it also heats the seawater. The heated seawater is returned to the ocean because extracting the heat is not yet practical.

At San Diego Gas & Electric's fossil fuel power plant in Encina, hundreds of lobsters, from the larval stage to a few imposing twelve-pounders, thrive in the warm seawater in the aquaculture laboratory. The larvae are cultured in constantly circulating water in large conical tanks. Juvenile and adult lobsters are housed in racks of containers stacked from floor to ceiling. Other juveniles are in a "Care-O-Cell," a circular tank containing individual rearing containers which rotate about a central axis. Mechanical arms radiate out over the culture system to supply the lobsters with aerated water and food.

Plants, Too

Mollusks, crustaceans, and fishes are not the only marine organisms that can be cultured in an aquatic environment. Plants, both terrestrial and marine, can also adapt well to controlled rearing conditions.

Marine algae, commonly known as seaweed, can be cultivated for food and for certain chemicals, known as colloids, which are of great importance to industry.

Two types of algae are of particular importance. Carrageenophytes are red algae that produce carrageenan, a colloid that is used as a stabilizer and emulsifier in pharmaceuticals, in foods such as ice cream and canned milk, and in beer. Agarophytes produce agar, which is also used by the food and pharmaceutical industries and is vital as a basis for certain microbiological techniques used in the diagnosis of bacterial infections.

Both agar and carrageenan are widely used in the United States. Most of the seaweeds from which these colloids are extracted must be imported. The United States harvests about five hundred tons of carrageenan-bearing algae a year, and twenty-five hundred to thirty-five hundred tons of the substance are used.

Dr. William Doyle and Dr. Judith Hansen, biologists at the University of California, Santa Cruz, are studying *Iridaea cordata*, a carrageenophyte which grows in the lower intertidal zone. They are developing culture systems so that this alga can be planted and cultivated for a stable yield.

They have devised two systems for culturing the *Iridaea*, in tanks and on nets. Tank culture is mainly for lab study of the development of juvenile plants in circulating seawater.

In net culture, nylon fish nets are "planted" with young *Iridaea* spores that have been grown in the laboratory to a length of five millimeters (about two-tenths of an inch). The net is attached to a plastic frame which is moored in the open ocean. Harvesting is merely a matter of retrieving the frame and collecting the seaweed.

There are over sixty carrageenophyte alga species, but only fifteen species produce agar. These agarophytes grow quite slowly compared to carrageenophytes. The United States must import most of its agar from Japan, and the price of agar has tripled in the past two years.

Dr. Hansen is studying culture techniques for *Gelidium*, an agarophyte, in the hopes of increase agar production for biomedical purposes. Her project is sponsored by Sea Grant and by Marine Colloids Ltd., a company interested in the high quality agar that *Gelidium* yields. "The ultimate objective here is to prescribe aquaculture conditions for growing stable, domestic crops for biomedical purposes," says Hansen.

Dr. Isabella Abbott, a biologist at Stanford University, is concerned with the need for agar for medical work. She is studying carrageenophytes that grow off the central California coast, looking for species that yield a high quality carrageenan that can be used as a substitute for agar.

Marine algae are not the only plants that grow in salt water. Dr. Emanuel Epstein, a plant nutritionist at the University of California, Davis, has been working to develop popular food crops that can use seawater on a stretch of sand a half mile from the ocean at the Bodega Marine Laboratory, Epstein is growing hardy barley, tomato, and wheat plants. These are hardly considered marine plants, but they are being irrigated with seawater.

Using seawater for agricultural plants is certainly unusual. But according to Epstein, "Some of the globe's wild plant life thrives in highly saline media—in the oceans, along their shores, in estuaries, in deltas, in salt marshes, and in saline desert soils." Certain species of plant life can withstand water with a salt concentration approaching, or equal to, seawater. Epstein is working to find and breed commercial plants with a high tolerance of salt.

Epstein and his students have developed barley strains which will grow in 100 percent seawater, and they have found wheat strains tolerant to 50 percent seawater. Eating-quality tomatoes have been crossbred with a small, inedible species from the Galapagos Islands to yield a plant which will grow in 70 percent seawater and yield fruit the size of cherry tomatoes. So far, estimates of yield are available only for barley. The numbers are good—the three top yielding barley lines approached the 1975 value for average world yield.

Besides being an abundant and readily available source of water, seawater is also a source of most mineral nutrients, which are often provided to plants irrigated with fresh water by applications of fertilizer.

Abalones, scallops, lobsters, algae, and land-based crops—all these items may be grown and cultivated in a controlled manner, using the ocean's waters. Just as technology has advanced the practice of agriculture, so may investigations into the biology and ecology of these and other marine plant and animal species increase the world's available food supply.

Supplemental Readings

The National Sea Grant office operates a computer search service for information on growing marine, brackish, and freshwater organisms. A $10 fee is usually charged. More information can be obtained from James Lanier, Virginia Institute of Marine Science, Gloucester Point, Virginia 23602, (804) 642-2111, x189, or contact the NADC Liaison Officer, NMFS-NOAA, PO Box 271, La Jolla, California 92037

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NEW MARINE PRODUCTS— Searching the Sea

The oceans have long served as a source of food, a mode of transportation, and a site for recreation. Scientists today are finding new uses for the ocean and its products—energy from offshore oil deposits and increased food production from aquaculture techniques are but two examples. The search for biologically active chemicals from marine plants and animals which have pharmaceutical or pesticide activity is a new and growing area of investigation.

"There is a wealth of plants in the terrestrial domain that have been the basis of drugs back to early Egyptian medicine," says Dr. Robert Jacobs, a pharmacologist at the University of California, Santa Barbara. "Marine products represent an untapped area—there is no reason we should stop the search for new drugs at the beach."

Nineteenth and twentieth century chemists studied old remedies to determine their active components. Once determined, these ingredients could be synthesized in the laboratory and altered to obtain higher potency, lower toxicity, or slightly different effects. Almost 50 percent of the prescription drugs available today are derived from natural sources. In addition, many drugs have been developed as a result of the understanding of the relationships of biological effects and chemical structure that resulted from studies of natural compounds.

A New Source

The marine world is a new source of chemicals with pharmaceutical applications. Scientists are observing interactions between sea plants and animals in order to make educated guesses as to which organisms may contain or secrete chemicals that affect other organisms.

"We watch what happens when two organisms meet," says Dr. John Faulkner, a researcher in new marine products at the Scripps Institution of Oceanography. "We study the basic nature of the communication." If other organisms avoid or seem repelled by a plant or animal, or if they are attracted in the absence of a visual or auditory stimulus, it may mean a potent chemical is being secreted.

Faulkner's research, sponsored by a grant from the National Science Foundation and by Sea Grant, is aimed at isolating chemical compounds from marine organisms. He and his co-workers are concentrating on stationary soft-bodied organisms such as sponges. Faulkner believes that since these organisms lack both physical protection and the ability to escape, they

"Marine products represent an untapped area—there is no reason we should stop the search for new drugs at the beach."

are most likely to have developed a chemical defense mechanism against predators.

Plant and animal species collected in the tropics and off the California coast are brought back to the La Jolla laboratory, where purified chemicals are separated out and assayed for antibiotic activity. Faulkner has found that tropical algae, sponges, and corals are more likely to contain chemicals that exhibit antibiotic activity than their counterparts from more temperate regions.

Insecticides, Too

Insecticides, too, have for the most part been derived from land-based compounds. Insect sprays such as "Raid" include naturally derived components, such as rotenone, from plants of the legume family; nicotine, from the tobacco plant; and pyrethrin, from the flower of a species of chrysanthemum.

Dr. Phillip Crews, a chemist at the University of California, Santa Cruz, has screened extracts from seaweeds collected in waters off the central California coast for possible insecticide activity. He has found that extracts from plants of the red algae family are roughly as potent as commercial insecticides. Crews is now working to isolate the active chemicals and analyze their insect control activity.

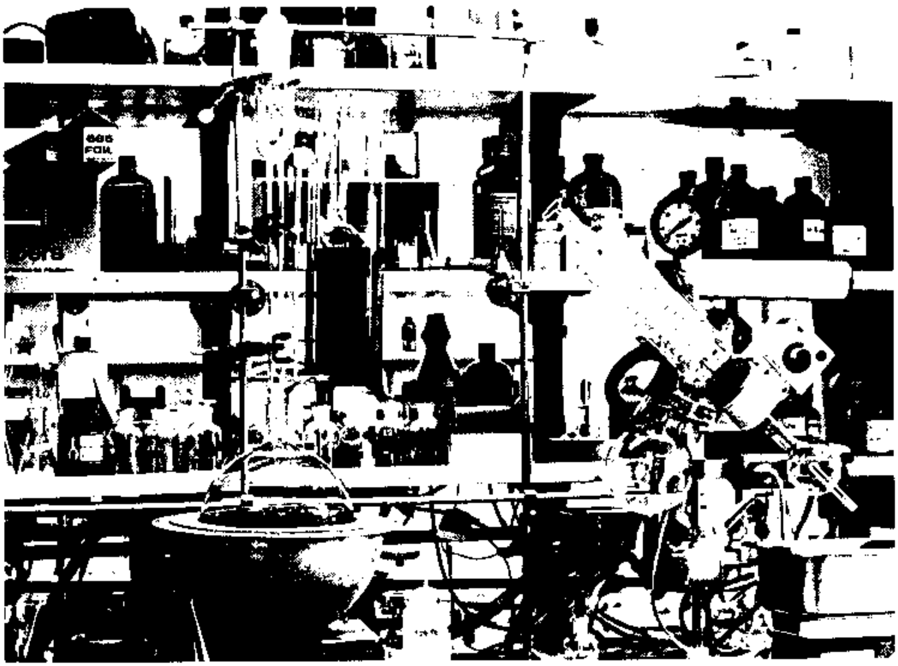
There are already a few marine-based pesticides on the market, Crews notes. "Seaborn" is used on certain crops to increase their resistance to pests and molds, and other seaweed extracts are used to increase the shelf life of fruits. And an insecticide in use in Japan, "Padan," was developed as a consequence of observations by fishermen, who noticed that insects which landed on a particular species of marine worm quickly perished. The natural toxin was then isolated from the worm and developed into an insecticide.

Dr. William Fenical, a research chemist at the Scripps Institution of Oceanography and the Institute of Marine Resources, is also looking for new pesticides from marine organisms. Fenical notes that although a number of pesticides currently in use are derived from natural products, most of the new pesticides are synthetics, and were selected for their potency rather than for their ability to break down into harmless chemicals in the environment.

Fenical says, "Insects have the ability to increase their resistance toward commercial insecticides. New products with higher insect selectivities and with lower mammalian toxicities must be developed. Naturally occurring compounds form an untapped resource for such materials, and there's an extra plus—they are often easily biodegradable."

Fenical and his associates are surveying natural marine organisms for possible agricultural applications. Their research has yielded a number of positive results, including two patentable chemicals with insecticide activity. The National Science Foundation is funding the laboratory's basic research in chemistry and communication of marine organisms. Sea Grant and the Zoecon Corporation, a pesticide manufacturer, are funding the work in the development of new insecticides.

Research in new marine products



involves more than just finding potent chemicals. Fenical explains. "We're doing basic research into physiologically active substances that are produced by marine organisms. When we find them, we learn where and why they're produced and we learn more about behavioral biology and natural toxicology."

Medical Applications

Dr. Robert Jacobs performs complete pharmacological evaluations of the substances being isolated by Drs. Fenical, Crews, and Faulkner. He looks at the biological activity of the compounds in tissues, organs, and animals. Where he finds an indication of pharmacological activity, he analyzes the chemical's structure and activity.

Jacobs notes that products isolated from marine organisms could be used for the treatment or relief of disease. He is optimistic about finding useful drugs from marine products, and states two reasons: first, marine organisms exist in an environment where communication and defense are often chemical functions; and second, the chemicals which have been isolated thus far have unique structures. "Marine products come from living things in the ocean, which is primarily a chemical environment," says Jacobs. "The organisms do things chemically to survive. Many of the chemicals associated with marine organisms have unique structures, and because of these unique structures they may have unusual activity."

An alga with unique activity is the focus of a research project at the Naval Biosciences Laboratory at the University of California, Berkeley. Dr. Neylan Vedros, director of the laboratory, is working with an alga that is active against herpes simplex virus, which is responsible for a wide variety of illnesses, including cold sores, fever blisters, infections of internal organs, and perhaps cancer. There is no known cure for this type of virus.

Dr. E.F. Deig and Dr. M. Hatch, working on the project along with Vedros, discovered the antiviral activity of a certain red seaweed while screening many different sorts of algae for the U.S. Navy. Deig, Hatch, and Vedros have tested extracts from the alga, and have found that mice given the extracts before they are exposed to the virus are able to withstand infection. Currently, the investigators are studying the ability of the algal extracts to aid laboratory animals to recover from the herpes infection. A number of safety tests must be performed before the drug may be tried on people.

These five scientists are working hard to locate new active chemicals from organisms which exist in an environment where communication and defense are often based on chemical activity. There is much to investigate in this "untapped area." Will the investigations yield usable compounds? As Dr. Robert Jacobs says, "Because the dimensions of the ocean and the diversity of the plants and animals in it is so great, we feel the probability of success is optimum. We can't guarantee success, but the chances look good."

"Marine products come from living things in the ocean, which is primarily a chemical environment. The organisms do things chemically to survive."

MARINE EDUCATION—A Chance to Learn

California's 1100-mile coastline borders a rich and generous resource: the Pacific Ocean. Californians derive much pleasure from the ocean, which also provides food, minerals, pharmaceuticals, and energy. How these resources can best be used, managed, and allocated is often a topic of debate.

Many groups are involved in these debates. The California Coastal Commission, local governments, the State Energy Commission, and National Marine Fisheries are just a few. These groups can make wise decisions only when they have access to sound information about the effects of tapping the ocean's resources on both people and the sea itself.

Providing the general public with sound information is the aim of the California Sea Grant Marine Advisory and Marine Education Programs. Marine advisors must transfer information to people already involved in marine activities—fishermen, kelp harvesters, skin divers—while marine education is generally for the decision makers of the future: students.

"Adults are most likely to get involved and interested in areas when an issue is present," says Don Wilkie, curator of the T. Wayland Vaughan Aquarium-Museum at Scripps Institution of Oceanography. "The tuna-porpoise problem, the otter situation, offshore drilling, coastal power plants—many of these issues are colored by strong emotions. Children, on the other hand, can be taught an objective approach when dealing with information."

Wilkie and the staff at the Scripps aquarium have developed an extensive education program that combines classroom instruction, field trips, and lectures to inform the public and interest children in marine geology, biology, and oceanography.

On any school-day morning, visitors to the aquarium are likely to find themselves surrounded by eager schoolchildren peering into tanks and asking questions: "Do turtles breathe air? What do moray eels eat? Can starfish swim?" Each academic year, the aquarium's troop of volunteer teachers, called docents, conduct over 60,000 students of all ages on tours of the aquarium's tanks, museum, and man-made tide pool. In an intensive lecture/field trip series each fall, these docents are specially trained to answer questions and explain exhibits.

Docents also bring mini-marine biology, oceanography, and conservation courses to classrooms in the aquarium's outreach program. They give slide-illustrated lectures and bring marine specimens to schools that are either preparing for aquarium field trips, or are unable to go.

The Scripps aquarium education program emphasizes exposing children to marine organisms and oceanographic concepts. Often, children who begin the

tour with apprehension for eels, urchins, and sharks, want to explore tide pools and even touch an urchin at the end of the hour. Sparking positive interest may be the first step in encouraging students to become informed citizens who make, as Wilkie hopes, "decisions through an objective understanding of the issues."

For students already interested in the sea, the aquarium offers summer courses in marine ecology. Selected high school and college students seeking careers in marine sciences receive training in laboratory techniques and aquarium management, and attend field trips and lectures by experts in marine subjects ranging from anemones to zebra fish.

Aquarium staff also provide advisory services to the general public, teachers, other aquaria, and zoos through audiovisual materials, fact sheets and brochures, and personal consultation. Wilkie says, "Scripps Institution of Oceanography has a high degree of credibility in the eyes of students, teachers, and the public. People come to Scripps with questions because they know they will receive accurate information. From its beginning, this institution has welcomed the public, to acquaint it with the work of Scripps and the importance of the oceans."

Up the coast from Scripps, the Santa Barbara community already understands the importance of the oceans. Researchers at the University of California, Santa Barbara, Marine Science Institute, have been unable to accommodate all the visitors interested in learning about marine research and seeing marine organisms. Six years ago, research specialist David Coon helped initiate a special open house program for community groups to meet the need for scheduled opportunities to see what was going on at the Marine Science Institute.

"We brought people in, gave them a tour of the research facilities and aquarium exhibits, and showed slides and movies," says Coon. "It became apparent that the demand was greater than we anticipated, because we were literally swamped by requests from school groups and community organizations."

The program has grown since the first open house. During four days of each quarter break, graduate and undergraduate biology students guide up to sixty people an hour on a tour of the facilities and exhibits. Visitors can view small aquariums, see slides, and peer through microscopes to get a close look at the sea's microscopic inhabitants.

"The hits of the show are the touch tanks," says Coon. "These are large shallow tanks that contain organisms, which, in our experience over the last four years, can usually survive four days of handling." Visitors may pick up scallops, urchins, crabs, and snails, compare textures, feel seaweeds, and closely examine organisms that many people have never seen or touched before. Other tanks are stocked with larger organisms such as sharks, lobsters, abalones, and fishes.

"Often, when the tour is over," says Coon, "an hour hasn't been enough, so the docents may take a group down on a beach walk. We can reach people year-round when we develop some self-guided tours of the beach and lagoon areas. The marine laboratory open house has been good for providing a link between the community and the university."

Bill Doyle, biologist at the University of California, Santa Cruz (UCSC), agrees with Coon's "hands-on" approach to marine education. He has been developing a program over the last two years that combines classroom presentations with outdoor field trips.

Undergraduates from UCSC talk to fourth graders about intertidal plants and animals, show slides, and pass around preserved specimens. The class goes on a field trip to an intertidal area adjacent to Natural Bridges Beach State Park, where other UCSC students act as guides to point out the organisms the children saw in the slides, and to explain some concepts of marine ecology.

Usually about fifteen students a quarter give tours and presentations. All of them have strong biology backgrounds and have taken at least one specific marine biology course. UCSC students work closely with the Santa Cruz City Museum and Santa Cruz teachers to develop the slide show presentation. The UCSC Environmental Studies Internship Program currently coordinates Doyle's program and grants academic credit to student interns.

Doyle says, "A major focus of the program is to combine indoor and outdoor education. We intend to introduce young children to the abundance of coastal resources, and to the fragility of the intertidal environment." He says student interns try to show the children how they can enjoy the coast without disturbing it.

Schoolchildren find it easy to enjoy themselves on a field trip to Natural Bridges. Low tide exposes a broad, rocky platform, and as waves crash offshore, children can squat, safe and dry, around a life-filled pool. They can examine prickly sea urchins, and laugh at brilliant orange starfish that wave their tube feet madly when pried off a rock. Some days, if the wind is right, children can hear the cacophonous barking of sea lions that congregate on an offshore rock about a mile down the coast. The children's exuberance for getting a good look at things often stretches a tour to as long as two hours.

In time, these and the numerous other marine education programs along California's coast may result in an informed public that is able to make wise decisions about marine issues.

"In the next few years, the world's growing population must face vital issues, many of which center on the ocean," says Wilkie. "Pollution, energy, fresh water, transportation, minerals, and food—decisions must be made in all of these areas. The public will influence those decisions and should do so from an objective, informed point of view."

THE MARINE ADVISORY PROGRAM— Knowledge at Work

An abalone fisherman wants to know how government regulations will affect his profits. A schoolteacher wants the latest information on sea otters and kelp forests. A coastal county planning committee needs wetland productivity and sensitivity data. A group of ocean-front homeowners wants to know how the cyclic movements of sand and water will affect their property.

California researchers are currently investigating these and other marine resource subjects, but their research may be inaccessible to the people who could benefit from it. Seeking specific information within a general topic can be exasperating, if not impossible, for anyone unfamiliar with a particular discipline and its specialized terminology.

Public demand for up-to-date technical information about marine resources has created a need for a direct link between university researchers and California citizens. The University of California Sea Grant College Program meets that need through its Marine Advisory Program.

The University of California's Cooperative Extension and Sea Grant College Programs together coordinate the advisory services. Three specialists at the program headquarters in Davis respond to particular information needs regarding marine resources, seafood technology, and aquaculture. To disseminate general information, seven regional advisors cover California's fifteen coastal counties.

The advisors' tasks are diverse, but overall, each advisor tries to make technical information available and comprehensible to anyone who asks for it. To do so, they draw from a wide variety of sources—from university publications and technical journals; from federal, state, and local agencies; and from individuals and industries. The advisors must keep up with new developments in the marine resources field and with the needs of the communities they serve.

Maynard Cummings, the advisory program's statewide coordinator explains, "The interests of the community are reflected in the activities of the advisor. However, he may also be able to point out some things the local people aren't aware of. What he *won't* do is go down to the waterfront and say 'I'm the expert from the university, here's your problem and I'm here to solve it.' The

"An advisor can't just turn off a person who's asked a question by saying, 'I'll go back and tell the researcher about this.'"

"It's *Sea* Grant, not 'fish grant.'"

advisor has to earn a reputation for being a source of information."

The advisors' methods of offering sound information are as diverse as their ways of gathering it. They sponsor workshops and short-courses, publish pamphlets and newsletters. They talk to schools and clubs, agencies and corporations. They spend a great deal of time conferring with groups and individuals to answer special questions.

Cummings emphasizes the responsive nature of the Marine Advisory Program. He says, "An advisor can't just turn off a person who's asked a question by saying, 'I'll go back and tell the researcher about this.' He tries to find the answer himself. But he may have to say, 'There isn't an answer on the shelf for this, so let's see if we can develop one.'"

To develop those answers, the advisors collaborate with both the researchers and the people in need; they contribute to the research efforts while encouraging the exchange of information and ideas between marine resource users and scientists.

Cummings explains that many of the collaborative efforts are directed towards the concerns of fishermen because "that's where we have the greatest immediate stock of information. But other areas—marine education, transportation, economics and recreation, and coastal zone planning—are just as important. It's *Sea* Grant, not 'fish grant,'" says Cummings.

In the course of providing information on coastal resources, the advisors sometimes find themselves in the midst

of controversy. Cummings says, "We can talk about issues like the tuna-porpoise problem or the sea otter-abalone controversy so long as we stick to the facts. We're in the business of furnishing independent advice and information." Cummings notes that unlike regulatory agencies, which may provide the same kinds of information, the university marine advisors don't advocate any particular points of view.

The advisors' credibility with the public results from their unbiased attitudes, Cummings explains. "We're not proprietary about our information, or necessarily selective. We don't say that the only things you ought to read come from the University of California." Nor can the advisors "pick and choose" their audiences. In theory and in practice, the advisors and their informational resources are accessible to anyone in California who has questions about the ocean and the coastal zone.

"We don't say that the only things you ought to read come from the University of California."

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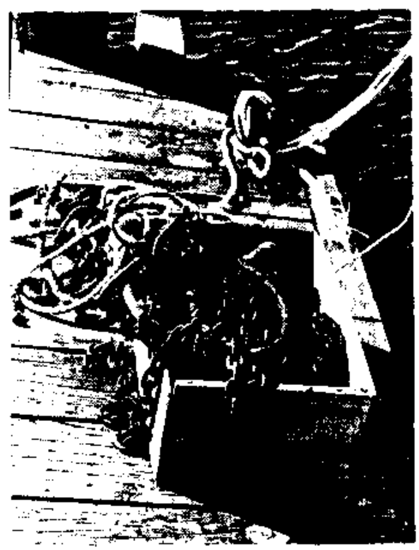

University of California Sea Grant Projects 1970-1977

Project Title/Project Leader

PROGRAM MANAGEMENT

Management and Program Development (Sullivan)

EDUCATION/TRAINING

Sea Grant Trainees (Sullivan)

Undergraduate Training in Marine Technology (Flittner)

Model Course in Marine Planning (Burton)

Graduate Education in Applied Ocean Science (Anderson)

Sea Grant Trainees (Frautschy)

Scientific Diving Supervisor Training (Stewart)

Sea Grant Educational Services (Hurley)

Graduate Education in Marine Biomedicine (Elsner)

ADVISORY

Ocean Education for the Public (Wilkie)

Marine Advisory Services (Cummings)

Publications and Public Advisory Services (Sullivan)

Ocean Engineering Data Center (Johnson)

Geophysical and Geological Data Center for Information on Petroleum Resources (Chase)

Improvement of Methods of Predicting Sea-Surface Temperatures (Gibson)

Marine Advisory Services Expansion (Flittner)

San Diego Law Review (Bratton)

Extension Education in Oceanography for Engineers: Survey of Need, Planning, and Development of Course Sequence (Chamberlain)

Support of Albacore Advisory Service Radio Broadcasts (Short)

COASTAL RESOURCES RESEARCH

Predictive Methods and Information Systems in Coastal Zone Management (Twiss)

Physical Criteria for Coastal Planning (Inman/Winant)

Ecological Studies of the Nearshore Zone (Dayton)

Determination of Physical Changes of Southern California Coastal Lagoons (Phillips)

Oceanographic Inventory of the Southern California Shelf (Fischer/Berry)

Subtidal Ecology of Carmel Bay (Thompson)

Management of Beach and Dune Vegetation (Barbour)

Diving Safety Research Project (Egstrom)

Coastal Plan Preparation (Sullivan)

Management of Cumulative Impacts of Coastal Development (Dickert)

Issues of Coastal Governance (Lee/Scott)

San Francisco Bay Project: Reference Collection, Bibliography, Identification Keys and Specimen Depository (Lee)

Coastal Engineering Data Network (Isaacs)

Tilting Spar Directional Wave Sensor (Inman/Guza)

Coastal Wetlands Management: Biological Criteria (Holmes/Peterson)

Coastal Wetlands Management: Effects of Disturbance on Estuarine Function (Zedler/Mauriello)

Coastal Wetlands Management: Opening of Coastal Lagoons by Sand Fluidization (Inman/Nordstrom)

Longshore Sand Transport Studies (Inman)

Model Coastal Ordinance Project (Molley)

Development of a California Coastal Wetlands Information Directory for Resources Management (Dickert/Pepper)

Marine Resource Evaluation of Humboldt and Del Norte Counties, California: Preliminary Investigations (Isaacs/Kerstetter)

Geology, Faulting, and Related Seacliff Erosion, San Dieguito River to Carlsbad, San Diego County, California (Shepard)

Fiscal Impact of Park Acquisition in Laguna Beach (Dickert)

Transportation Analysis in the Coast Zone: Subregional Considerations for Local Coastal Plans (Dickert)

Physical Criteria for Thermal Discharges in Coastal Water (Winant)

Internal Waves Over Shelf and Canyon (Cox)

Assessment of the Offshore Commercial Sand and Gravel Potential on the Central California Continental Shelf (Berry/Wilde)

Methods for the Management of the Cumulative Impacts of Coastal Development (Dickert/Twiss)

Coastal Governance in California (Lee/Scott)

Half Moon Bay Private Sector Impact Study (Goldman)

Development of Interpretive Methods and Materials for Marine Parks in Northern California (DeMartini)

Development and Assessment of Legally Permissible Methods for Coastal Management (Heyman)

The Potential Environmental Impact of the Japanese Alga, *Sargassum muticum* (Dayton)

Biological and Ecological Studies of Normal Populations (Newman)

Ecology of Santa Cruz and San Mateo County Coasts (Doyle)

Natural Seepage in the Santa Barbara Channel: Physiochemical Aspects (Mikolai)

Seismicity and Earthquake Hazards of the Sanata Barbara Channel Area (Sylvester)

Sea Coast Planning Project (Hetrick, *et al.*)

Monitoring of Pollution Parameters in San Francisco Bay (Wilde)

Recreation Resources of Los Angeles County Coast (Egstrom)

Trace Metal Analysis of Oily Beach Pollutants in the Santa Barbara Channel (Mikolai)

Organizational Arrangements for Coastal Management (Lee/Scott)

Experimental Study of the Tomales Bay "Sneaker Wave" (Fischer)

Legal Techniques for Marine Resources Management (Bowden)

Design of a Computer-Automated Map (Pepper)

AQUACULTURE RESEARCH AND DEVELOPMENT

Economics of Aquaculture (Johnston)

Development of Aquaculture Systems (Shleser)

Use of Thermal Effluent in Aquaculture (Ford/Van Olst)

Seaweed Resource Management (Neushul/Coon)

Salt-Tolerant Plants (Epstein)

Development of a Commercial Aquaculture System for the Crab *Scylla Serrata* (Harrison)

Marine Ecology of the Central California Coast (Doyle)

Kelp Forest Ecology of the Central California Coast (Pearse)

Kelp Bed Mariculture and Resource Management (Neushul *et al.*)

A Genetic Program for Improvement of Carrageenan in Red Algae *Gigartina* (West)

Effects of Public Regulations on the California Aquaculture Industry (Bowden)

The Development of the Science and Technology of Aquaculture (Hand)

Optimization of an Artificial Diet for Lobsters (Holtz)

Use of Thermal Effluent in the Culture of Crustacea and Fishes (Van Olst/Ford)

Biochemical and Genetic Control Applied to the Critical Stages in Culturing Abalone (Morse)

Surfperch Mariculture (Norris)

Aquaculture of the Purple-Hinge Rock Scallop (Phleger/Leighton)

Carrageenophyte Cultivation, Genetics, Population Dynamics, and Development of Agar Substitutes (Doyle/West/Abbott)

Toward Seawater-Based Crop Production (Epstein)

Astaxanthin from Yeast (Lewis)

The Role of Diseases in Aquaculture: Preliminary Survey (Raggi)

Plant Pathogens of Aquaculture Systems (Goff)

Bioeconomic Modeling of the Freshwater Prawn *Macrobrachium* spp. (Johnston)

Food Conversion Efficiencies of Instar Dungeness Crab (Tulles)

Uses of Waste in Aquaculture (Cooper/Holms)

Rearing of Larval Fishes (Lasker)

California Spiny Lobster Growth (Dexter)

Pesticides in the Plankton and Fish of the California Current (Longhurst/Lasker)

Abalone Culture (Leighton/Wilson)

Gelidium Resource Management (Barilotti)

FISHERIES RESEARCH AND DEVELOPMENT

The California Market Squid Fishery (Thompson/Frey)

Optimal Management of Sea Urchin Fisheries (Dayton)

Effects of Fishing Sea Urchins on the Marine Ecosystem (Connell)

Studies Toward the Optimal Management and Environmental Effects of Sea Urchin Fisheries (Dayton/Connell)

Determination of Appropriate Levels of Fees for Vessels Fishing for Yellowfin Tuna in the Eastern Tropical Pacific (Flagg)

New Antioxidants for Marine Lipids (Olcott)

Studies of Fish Muscle Proteins and Fresh and Frozen Seafood Technology (Brown)

Natural Fermentation of Marine Products (Crisan/Miller)

Histamine Toxicity from Fish Products (Olcott *et al.*)

An Enthnography of the San Pedro Wetfish Fishing Fleet (Velez)

Mass Culture of Toxic Dinoflagellates (Haxo)

Marine Resource Management Intern Research Program (Sullivan)

Socio-Economic Aspects of Expansion of the California Swordfish Fishery (Holt)

Coordinated Management of the Pacific Coast Salmon Fisheries and the Implications of Extended Jurisdiction (Wyner *et al.*)

Protective Immunization of Anadromous Salmonids Against *Aeromonas salmonicida* and *Vibrio anguillarum* (Kerstetter)

Development of a Mechanism to Allow Release of Dungeness Crabs from Lost or Abandoned Pots (Jolly)

Endocrinology of Salmon Smolification and Adaptation to Seawater (Bern)

The Social and Political Systems of the Tuna Fleet of San Diego and Ensenada: Their Place in International Cooperation and Competition for Marine Resources (D'Andrade)

Design and Development of a Squid Processing Machine (Singh)

Development of Trapping Methods for Migratory Salmonid Smolts in Hatcheries (Kerstetter)

Optimal Leasing Agreements for Marine Resource Development (Quirk/Lewis)

The Effects of Food Availability on the Growth and Survival of California Jack Mackerel Larvae (Mullin/Lasker)

Investigation of Data for an Economic Study of the U.S. Pacific Albacore Jig Boat Fishery (Holt)

Methods of Quality Assessment in Fishery Products (Chang)

Limited Entry: An Assessment for California Fisheries (Wyner/Harding)

Cause of the Decline in Dungeness Crabs in the San Francisco Bay Area (Horne)

Sand Bottom Community Structure and Artificial Reefs (Dayton)

A Study of the Santa Barbara Inshore Party Boat and Aspects of the Life History of the Olive Rockfish *Sebastes serranoides* (Ebeling)

Fishes of the Santa Barbara Kelp Forest (Ebeling)

The Juvenilizing Factor in Crustacean Eyestalks (Faulkner/O'Connor)

Ecology of Benthic Herbivores in the Sea (Connell/Murdoch)

Ecosystem Studies and Maricultural Potential of a Coastal Lagoon (Holmes)

California Spiny Lobster Fishery and Related Population Characteristics During Period of Reduced Fishing Effort (Farris)

Studies of Vertical Migration of Zooplankton (Enright/Isaacs)

Culture, Behavior and Physiology of the California Spiny Lobster *Panulirus interruptus* (Chase/Childress)

Feasibility of a Black Cod Trap Fishery in Monterey Bay (Cailliet)

NEW MARINE PRODUCTS

Marine Natural Products Chemistry (Faulkner)

Seaweed Products: Application in Algae Control, Mariculture and Agriculture (Fenical)

Naturally Occurring Halogenated Compounds: Their Interference in Pesticide Pollution Analysis (Fenical)

Antiviral Compounds from Algae as a Potential Marine Resource (Vedros)

Marine Natural Products Chemistry of Fouling Organisms (Faulkner)

Development of Antiviral Compounds from Marine Algae (Vedros)

Development of an Anticancer Substance from the Brown Seaweed *Dictyota* (Fenical)

Tissue Culture of *Macrocystis* and Related Seaweeds of Economic Importance (Lewin/Fenical)

Marine Plants as a Source of Insect Growth Inhibitors (Crews)

Natural Compounds from Marine Organisms (Sims)

ENERGY

Wave Climate Modification in Harbors by Dynamic Breakwater (Isaacs)

New Applied Developments (Isaacs)

Biological Effects of Waste Heat Effluents of Coastal Power Plants (Smith/Hand)

Stray Electrical Current Hazards to Prestressed Concrete Construction in Seawater (Cornet)

Earthquake Loading on Large Offshore Structures in Deep Water: A Study for the Correlation of Analytic and Physical Models (Wiegel *et al.*)

Seismic Hazards to the Development of Offshore Oil Resources (Prothero)

Power from Salinity Gradients (Isaacs)

Thermophilic Microorganisms Isolated from Undersea Hot Springs, Electric Power Plant Condensers and Ships/Heat Exchangers (Isaacs)

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Identification of Sources of Oil Spills in the Santa Barbara Channel (Profio)

Marine Vehicle Safety Analysis (Paulling/Webster)

OCEAN ENGINEERING

Enhancement of Natural Marine Productivity by Artificial Upwelling (Isaacs/Schmitt)

Unmanned Sea Floor Work Systems (Anderson)

Engineering Properties of Sea Floor Sediments (Noorany)

Synthesis of Forces on Marine Structures (Paulling)

Underwater Cable Dynamics (Webster)

Acoustic Holographic System for Underwater Search (Wade)

Composite Materials for Ocean Construction (Tetelman)

This booklet was written, illustrated, edited, and produced by four interns from the science writing program of the University of California, Santa Cruz. Shannon Brownlee drew the sketches and wrote the sections on Energy and Marine Education. Pat Murphy served as managing editor and wrote the section on Fishery Management. Sheridan Warrick wrote the sections on Coastal Zone Management and Marine Advisory Services. Joanne Silberner wrote the sections on Aquaculture and New Marine Products and served as photographer.

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The Sea Grant Program was created in 1966 by Public Law 89-688, the National Sea Grant College and Program Act. The purpose of the program is "to increase the understanding, assessment, development, utilization, and conservation of the Nation's ocean and coastal resources by providing assistance to promote a strong educational base, responsive research and training activities, and broad and prompt dissemination of knowledge and techniques."

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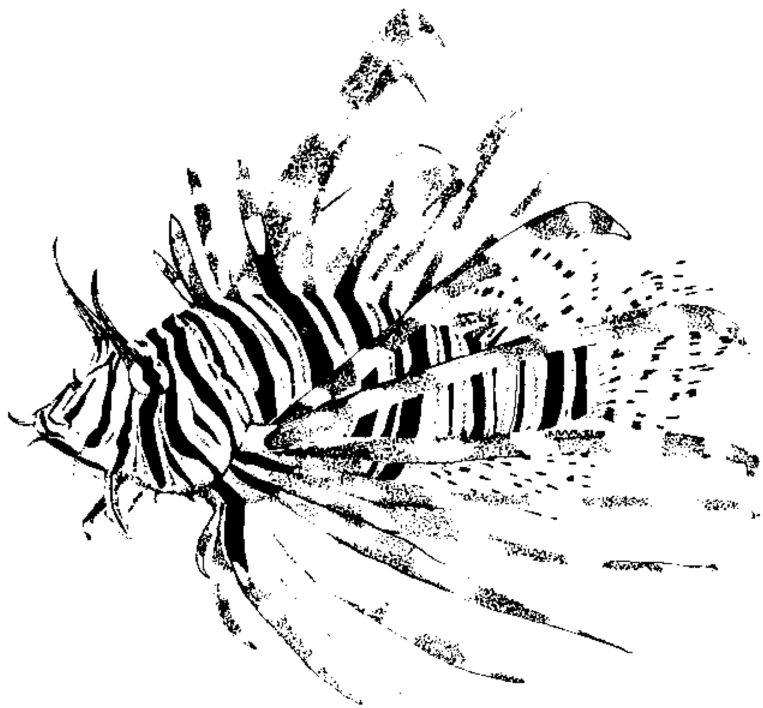

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