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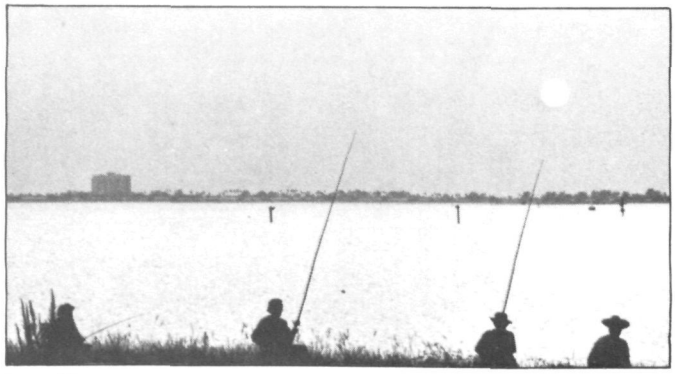
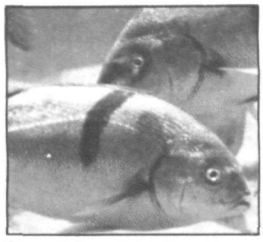
Cover:
Leisurely fishing by a quiet lagoon . . . like so many other activities, this could be threatened by problems of ocean pollution (see editorial and stories, pages 6 and 16).



Bernard Brandt



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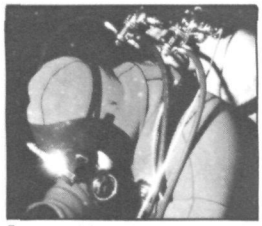

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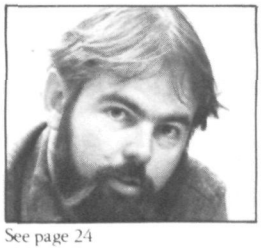

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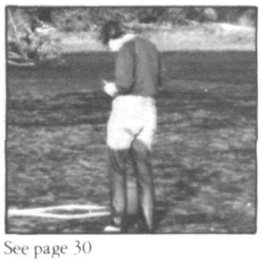

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Ocean Pollution is Everybody's Business

Ferris Webster
Assistant Administrator for Research and Development

That two articles in this issue of *NOAA* deal with aspects of ocean pollution is not wholly coincidental. Public concern and NOAA involvement in this critical problem are on the increase; indeed, every recent issue of this magazine has carried major stories on NOAA activities related to ocean pollution research and response.

The recently published *Federal Plan for Ocean Pollution Research, Development, and Monitoring* points out that when one considers the basic NOAA marine pollution activities together with work managed on behalf of other Federal agencies, ". . . NOAA ranks first in the direct conduct or management of Federal ocean pollution research, development, and monitoring programs." The research at the National Marine Fisheries Service Seattle laboratory and the Great Lakes Environmental Research Laboratory described in this issue is but a small part of the total agency involvement.

Questions of science and public policy raised by contamination of the oceans deserve the attention of all of us, as NOAA employees and as residents of planet Earth. Nuclear waste disposal, for example. Nuclear waste includes not just material from nuclear power plants, but residues of many industrial and medical uses. Japan is considering dumping in an area of the Pacific that it believes to be safe; European nations have for some time used a North Atlantic dumpsite. What are the problems? Are there alternatives?

We are also awakening to the problem of synthetic organics. Numbering in the thousands, they are widely used as solvents, pesticides, agricultural chemicals; they are necessary components of our complex industrial civilization. Some, such as Kepone and PCB's, are very persistent. Some have had unanticipated adverse effects on the marine environment, resulting in closed fisheries. NOAA research and monitoring can scarcely touch the whole range of problems they pose, but our efforts to identify those that are most troublesome are of fundamental importance.

A related question needing more attention is the extent to which the oceans can assimilate additional material. This goes beyond simply observing the effects of various materials, and asks: how much more can be put into the ocean? What are the social and economic tradeoffs to increased pollutant loadings?

Land-based alternatives that once looked so promising are becoming less acceptable. Threats to public health arising from chemical dumping in the Love Canal and abandoned coal mines are teaching us that the land, like the sea, is vulnerable.

Finally, we have to pay more attention to the cumulative effect of multiple contaiminants. With PCB's, heavy metals, and nutrients, for example, all entering or being dumped into an ocean area, what effects will they have on each other? Will this increase the overall deleterious effect on the sea? What is the limiting factor?

Answers to the many questions of ocean pollution must be sought rationally, carefully, and with some urgency. NOAA people have a crucial role to play in this effort—which is everybody's business.

A Seattle laboratory is searching for answers

WHAT'S HAPPENING TO OUR FISH?

Donald C. Malins

Dr. Malins is Director of the Environmental Conservation Division at NOAA's Northwest and Alaska Fisheries Center, Seattle, Washington.

Chemicals keep us alive, but they can also maim and kill. Some poisons continually threaten the fish in our waters and wetlands.

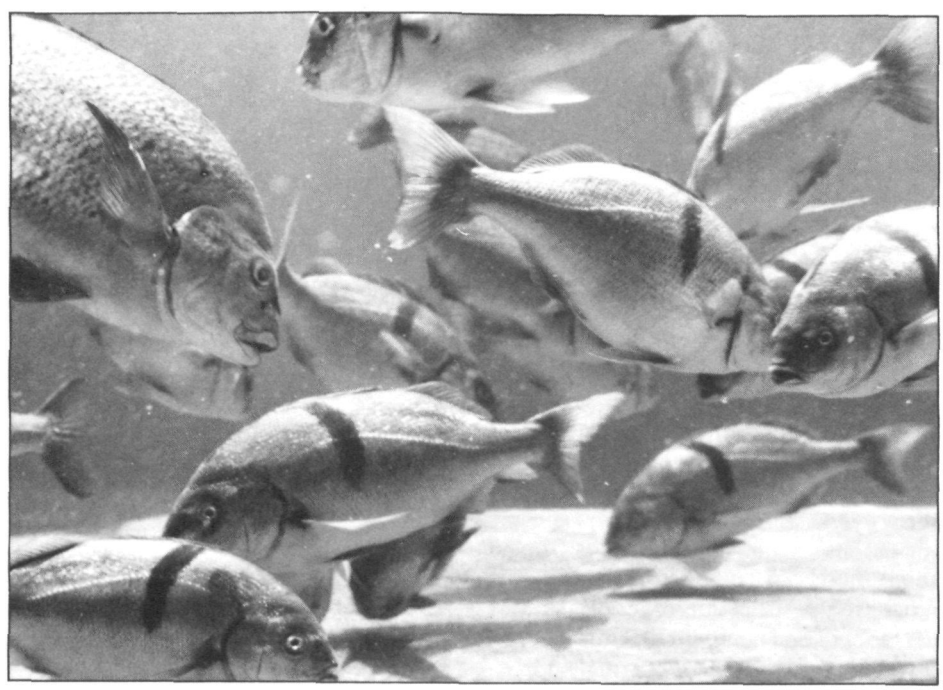
Catastrophic oil or chemical spills traumatically poison the environment. Other persistent low-level substances slowly and silently erode the well-being of humans, animals, and plants.

Pollutant interactions with living beings are complex. About 63,000 chemicals are commonly used today, and any one of them is a potential pollutant. So important are the effects of pollution on fish and fish habitats that the National Marine Fisheries Service, with its many divisions, has mounted a national program to study them. Its Environmental Conservation Division tries to understand how environmental stresses affect marine life—stresses such as petroleum, sewage, and many other organic and inorganic chemicals. We try to find out how much of the various contaminants a particular animal absorbs, what happens to the absorbed chemicals, and what changes they cause in behavior or tissue.

We work in the field and in the laboratory, comparing the functioning of normal and perturbed ecological systems. Our basic question: which pollutants are present in the environment and in what quantities? Our basic problem: many pollutants entering the environment turn into other potentially harmful compounds, all but eluding detection. How to find them?

National Analytical Facility scientists, directed by Dr. William MacLeod, are working to overcome this problem. Using new methods and sophisticated instruments, they have tracked down a wide array of pollutants put by man into the environment.

"Many of these contaminants are present at extremely low levels, down to one part in a billion," says MacLeod. "This may seem innocuous, but marine plants and animals can accumulate certain hazardous chemicals in their tissues to many thousands of times the levels found in the environment. Because of this concentration effect, ex-



Ewing Galloway

tremely low levels of environmental contaminants may pose a serious threat to marine organisms directly and to humans indirectly.''

Wouldn't highly mobile marine animals, given a choice, stay clear of harmful pollution? Not necessarily, says Douglas Weber of the Behavior and Developmental Biology Group: ''Our studies showed that salmon, flatfish, and crabs often did not move away from water or sediment contaminated with crude oil, even at harmful levels.''

In laboratory experiments, Weber's research group studied young Pacific salmon's reaction to water-soluble poisons in crude oil, mainly aromatic hydrocarbons. Given a choice between clean water and oil-contaminated water, the fish chose the clean water only after the hydrocarbon content exceeded the rather high level of 2.5 parts per million.

In other lab experiments, flatfish were released in a clean-sediment area but, to the scientists' surprise, fed just as actively in heavily oiled sediments. From these and other studies, it was concluded that salmon, flatfish, and crabs are potential victims of oil pollution.

Field tests on Pacific salmon migrating upstream to spawn bore out these findings. Controlled low-levels of hydrocarbons were added to the water in a fish ladder on one side of a dam; clean water flowed through a ladder on the other side.

Early in the migration, the fish avoided the contaminated ladder even when the hydrocarbon concentration was low. Later in the run, some salmon used the contaminated ladder despite higher levels of hydrocarbons.

In other field studies, our scientists found some flatfish with abnormalities such as liver tumors and worn fins. Many of these fish had come from waters high in municipal and industrial wastes containing PCB's (polychlorobiphenyls), metals, and petroleum hydrocarbons. Pathology Group scientists under Dr. Bruce McCain sought a causal relationship between poisons and abnormalities.

In laboratory experiments, English sole, which spend much of their lives buried in the sea bottom, were exposed to crude-oil-contaminated sediment for four months. They lost weight; some died. A control group of non-exposed fish lost less weight and looked healthy. The exposed fish also developed greater changes in liver-cell structure than did the controls.

Flatfish exposed to contaminated sediments for long periods indeed suffered harmful changes, including loss of weight and damage to skin and internal organs, the studies showed.

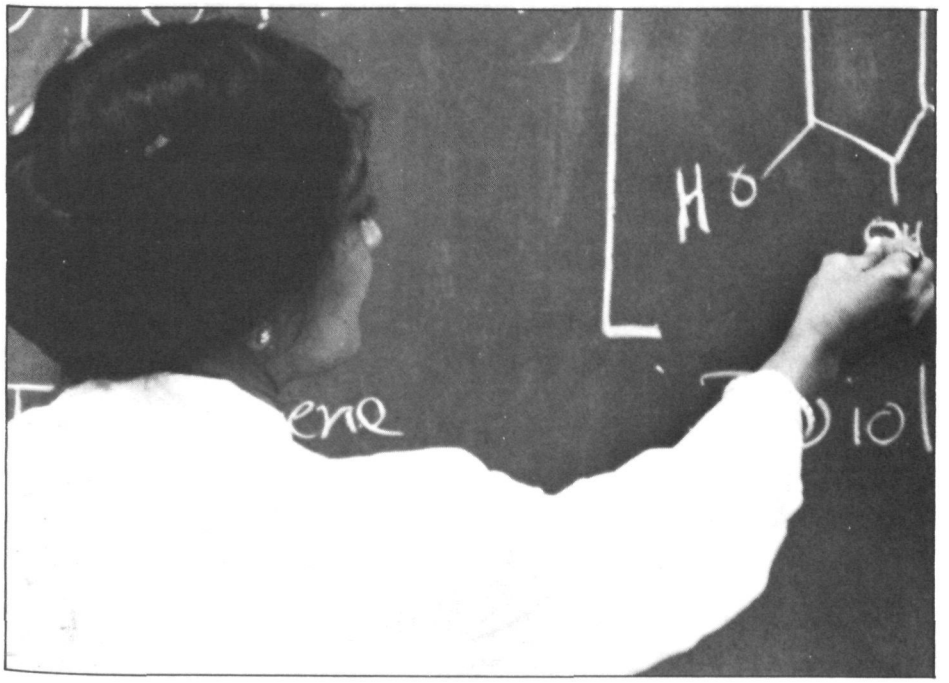
But changes in the behavior of fish and other marine life, as well as development of lesions, are not the only consequences of pollutants. Those easily seen changes are often accompanied by subtle shifts in the inner workings of cells and structural alterations visible only by electron microscopy. Dr. Joyce Hawkes, head of the Electron Microscopy Research Group, uses scanning and transmission electron microscopy to monitor the effects of pollutants on cells. [See ''The Small World of Joyce Hawkes,'' **NOAA**, January 1979.] Structural changes are correlated with other changes, such as alterations in behavior or physiology.

In laboratory experiments, fish were fed food containing crude oil. Dr. Hawkes and her group found that the livers of those fish lost carbohydrates and accumulated abnormally large amounts of fat. Apparently the hydrocarbons had disrupted normal liver functions. Some fish also developed cataracts.

Moving from the cell to the molecule, Dr. Usha Varanasi and the staff of the Biochemical Effects Group are asking how pollutants, particularly petroleum hydrocarbons and metals, interact with molecules in the cells of live animals.

All living cells contain protein and nucleic acids, such as DNA (deoxyribonucleic acid), which carry hereditary characteristics. Enzymes, a type of protein, serve as biochemical catalysts and are essential to cell viability. Chemical interactions change the structures of enzymes and DNA and their functions.

Dr. Varanasi's group found that flatfish can transform petroleum pollutants into new, oxygenated, highly toxic compounds that interact with DNA. Many scientists believe these new compounds cause irreversible cell damage, which sometimes leads to tumors. Such



Dr. Usha Varanasi (left), research chemist at the Northwest and Alaska Fisheries Center, discusses chemical effects of pollution on fish.

changes could disrupt the feeding and reproductive behavior essential to survival in the wild. PCB's, persistent contaminants in the marine system, cause concern about their effects on aquatic organisms. Dr. Edward Gruger of the Biochemical Effects Group studied the effects of low PCB levels on young coho salmon. He found that PCB's eaten in food accumulated in the fish and triggered changes in aromatic hydrocarbons in the liver. The results suggest that hydrocarbons (absorbed from oil spills, for example) are more readily metabolized in fish exposed to PCB's.

Dr. Harold Hodgins and the staff of the Contaminant Effects on Life Processes Group are studying the effects of pollutants on fish resistance to disease. "Changes in the health of fish," Dr. Hodgins comments, "reflect interactions among disease-producing agents, environmental factors, and the mechanisms by which fish resist disease. Any environmental change that unbalances these interactions may lower the fish's ability to resist disease."

In one study, fish were first exposed to pollutants, then to a marine bacterium that had devastated salmon on fish farms in the Pacific Northwest. Differences in the numbers of bacteria needed to kill pollutant-exposed and non-exposed fish were considered a pollutant's resistance-lowering quotient.

Coho salmon, flounder, and rock sole exposed to oil contaminants showed no marked changes in disease resistance. Nevertheless, under environmentally induced stress, food scarcity, for example, exposure to pollutants may heighten susceptibility to infections.

The extraordinary complexity of the marine environment becomes more apparent every day. Pollution caused by humans further complicates the system. Unraveling these puzzles calls for sophisticated ideas, methodical tests, and rigorous analysis.

Contaminants will always enter our environment. New chemicals to satisfy technological and economic demand will add to the environmental load.

NOAA scientists are working to deepen understanding of the behavior of contaminants in the ecosystem. With such information, sound decisions can be made to prevent or ease the effects of contamination on our world.

William D. Gronlund, fisheries biologist, takes sample from Elliott Bay, Seattle (opposite page) and (below, top photo) places young salmon in "decisions chamber" to see if it will enter water containing hydrocarbons. Another biologist, Mark S. Myers (bottom photo), dissects sole to determine effect of pollutants.

MARAUDERS IN THE RED RIVER VALLEY

Charna Lester

Charna Lester is a writer-editor with the Weather and Flood Warnings Coordination Staff, National Weather Service

Western desperadoes never spread fear the way the word "tornado" does. Neither did their raids cause the damage and casualties. In the Red River Valley of northern Texas and southern Oklahoma, which has known both, April 10, 1979, looked bad. Severe thunderstorms were forecast—the kind that spawn deadly twisters.

By late morning, the Texas panhandle was overrun by thunderstorms and their frequent companion, hail. At noon, eastern New Mexico and extreme western Texas felt the effects of strong southwesterly winds pushing dry warm air against a body of warm moist air in western and central Texas. Satellite pictures confirmed reports of strong dust swirls created by the strength of the dry, warm air flow.

Forecasters continued their watch, steadily adding new information to their data. By early afternoon, radar and satellite imagery showed explosive thunderstorm development.

1:55 p.m. The 67th tornado watch of 1979 goes out on National Weather Service communication circuits, telling

people to look out for tornados from 2:30 p.m. to 7:00 p.m. over a 30,000 square mile area from north central Texas into southwestern Oklahoma. A citizens' alert begins. NOAA Weather Wire and other teletype circuits carry the message to subscribers. NOAA Weather Radio broadcasts the first of many bulletins to listeners. National Warning System and local communication systems alert authorities and emergency service personnel. Within moments, all agencies responsible for citizens' safety know of the threat.

Wichita Falls Weather Service Office is responsible for warning an 11-county area. Skywarn Spotters, trained by NWS to observe and report severe weather, receive action alerts. Volunteer observers of the Foard County CB Club report to assigned locations, ready to receive and transmit threatening weather reports.

2:48 p.m. Hell breaks loose. Severe thunderstorms with strong gusty winds fling golf-ball-sized hailstones at Foard and Knox Counties.

2:50 p.m. Severe thunderstorm warnings are issued for Foard, Knox, and Hardeman Counties.

3:14 p.m. Funnel aloft sighted 6 miles east of Crowell, Tex. One injury and significant property damage reported in Foard County.

3:15 p.m. Police report tornado on Pease River. Thunderstorm warning for Wilbarger County changed to tornado warning. Citizens advised to take immediate precautions.

3:30 p.m. Warning sirens wail throughout Vernon, Tex. Deadly tornado strikes. In its wake: 11 dead, 70 injured, extensive property damage.

3:42 p.m. Severe thunderstorm continues northeastward into Tillman County, Okla. NWS Office in Oklahoma City contacts Tillman County Police and other Oklahoma City emergency services. Tornado heads straight for city of Davidson. NWS telephones Davidson's mayor. City's sirens sound; countless lives saved by fast response.

4:02 p.m. Davidson left reeling.

4:15 p.m. Oklahoma City NWS Office issues tornado warning for Tillman, Cotton, and Comanche Counties. NOAA Weather Radio, Lawton Civil Defense, and Lawton's news outlets broadcast alert.

5:05 p.m. Using spotters, local radar, and information from NWS Oklahoma City, Lawton Civil Defense tracks approaching storms. Lawton sounds warning sirens. Toll: 3 dead, 100 injured.

Meanwhile the line of severe thunderstorms has moved on and given birth to a new tornado just south of Harrold, Tex. Funnel bounces along a 64-mile path to Pumpkin Center, Okla.

4:40 p.m. Tornado careens into Grandfield, Okla. Commercial, NWR, and local TV stations rush to compile and broadcast news of fast-changing weather. People react quickly to media warnings and sirens.

The long-lasting sequence of severe thunderstorms also bears down on the city of Wichita Falls.

3:55 p.m. Volunteer storm spotters receive thunderstorm alert, leave jobs, grab raingear, check CB and Ham radios, and begin Skywarn vigil. Their training pays off. Every call contains valuable information. The low overcast of early day dissipates. Suddenly, the weather pattern changes.

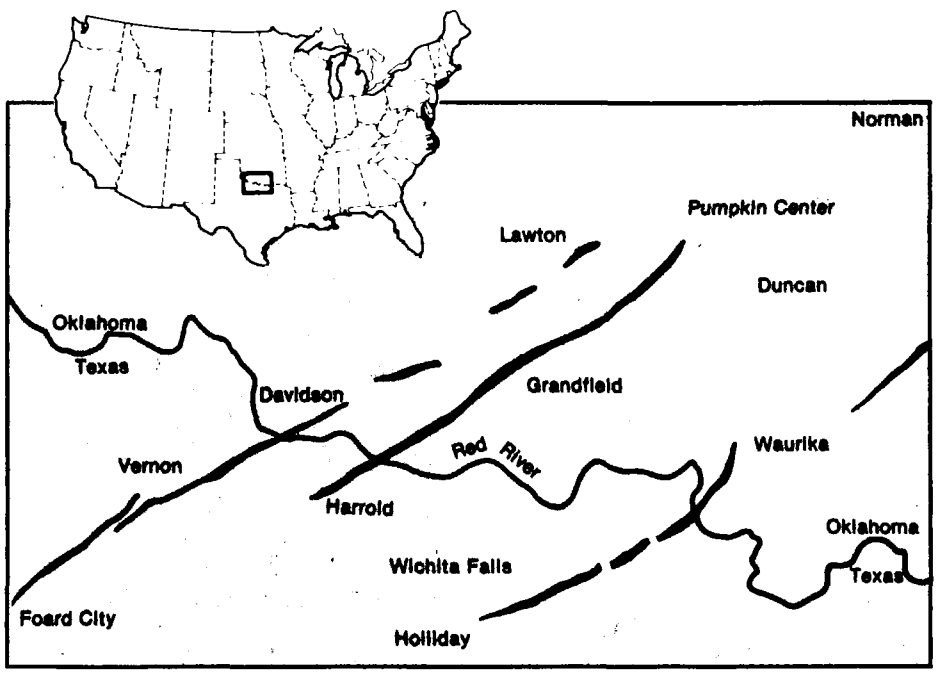
4:00 p.m. Texas Department of Public Safety reports tornado to NWS Office. Warning issued for northwestern Wichita County. Within minutes, focal person for the Two-Meter Repeater Club reports to Wichita Falls office for duty. His long vigil begins. Heavy rain soon produces rivulets in low-lying areas. Hail on roofs dulls the noise of wind, rain, and frequent thunder.

4:40 p.m. Severe thunderstorm warning for Baylor and Wichita Counties.

4:55 p.m. Baylor County Sheriff's Department reports tornado touch-down on northeast Seymour city limits. No damage to town, but winds uproot trees.

4:56 p.m. Tornado warning for Baylor County.

5:07 p.m. Skywarn spotter reports that a tornado funnel hit west of Iowa Park.



The Red River Valley of Oklahoma and Texas, showing paths of 10 of the 13 twisters that hit the area on April 10, 1979. Three others touched down to the northwest.

5:08 p.m. Spotter sights tornado moving in from west. Wichita Falls NWS Office issues tornado warning. Fire Department sounds warning sirens.

5:20 p.m. Tornado warning for Archer County. Telephone jangles in the Wichita Falls Weather Service Office. The well-alerted populace of the city sees approaching cloud of wind-trapped dirt and debris. Skywarn spotter 5 miles south of city sees twisting funnel drop from cloud.

6:02 p.m. Funnel broadens, hits southwest Wichita Falls, leveling everything in its path, and continues for 47 miles. Tornado warning extended to include Wichita County.

6:11 p.m. Tornado warning for Clay County.

6:18 p.m. Power blackout in Wichita Falls. All but Ham radio communications cease. Toll: 47 dead, 1,700 injured.

7:00 p.m. Weakened twister reaches Waurika, Okla. Severe weather continues for 24 hours in southern and eastern United States.

April 10, 1979, had dawned like many other spring days, but ended like few that area had ever seen. By day's end 13 tornados had touched down along three separate tracks, leaving their inevitable death, injuries, and destruction.

PREPARATION IS THE PAYOFF

Tornados have been recorded in the United States every month of the year. The peak season is spring. During any severe weather conditions, Weather Service personnel work with local officials and the media to tell citizens what to do should a weather disaster occur. With increasingly accurate forecasts and prompt news of severe weather events, local, county, and state officials are trying to improve citizen safety. Most NWS offices give technical assistance to police and fire departments and other organized groups involved in preparedness planning.

Last year many States proclaimed Tornado Awareness Days or Weeks, using radio, television, newspaper articles, and photographs to impress on people the damage tornados can do. These campaigns stressed local readiness and personal safety planning as effective means of reducing deaths, injuries, and property loss.

This message is echoed by the people in Wichita Falls who know what they're talking about. The Wichita Falls *Record News* said: "Action by the Wichita Falls office of the National Weather Service saved hundreds, perhaps even thousands of lives . . . "

Just the week before the tornado hit, Wichita Falls Civil Defense had conducted a full city-wide drill. Proper safety measures were fresh in the minds of residents who had participated. Less than a month before, on March 20, Frank Cannon, officer in charge of the Wichita Falls Weather Service Office had also held a spotter-training meeting for members of the Two-Meter Repeater Club. These two safety refreshers were part of a series started several years earlier that involved many government and private groups.

Warren Silver, vice-president and general manager of KFDX-TV, Wichita Falls, summarized the ways prior planning pays off when disaster strikes:

"Volunteer amateur mobile two-way radio operators, trained by and working directly with the local office of NWS, first reported the funnel . . . The NWS office acted without hesitation to get the warning out to the appropriate agencies . . . Sirens sounded and the warning was broadcast only minutes before the first damage occurred . . . Hundreds of lives were saved because the system worked . . . spotters were in the right place at the right time. This was not and must not be left to chance. Trained people with instantaneous communication capability are imperative. They must get to where the storm is, know where to watch, and know what to report. They did and it worked."

CARS CAN'T OUTRUN TORNADOS

Not everyone heeds warning sirens. Twenty-five of the 47 victims in Wichita Falls died trying to outrun the tornado in their cars. Ten of the 11 fatalities in Vernon involved people in cars.

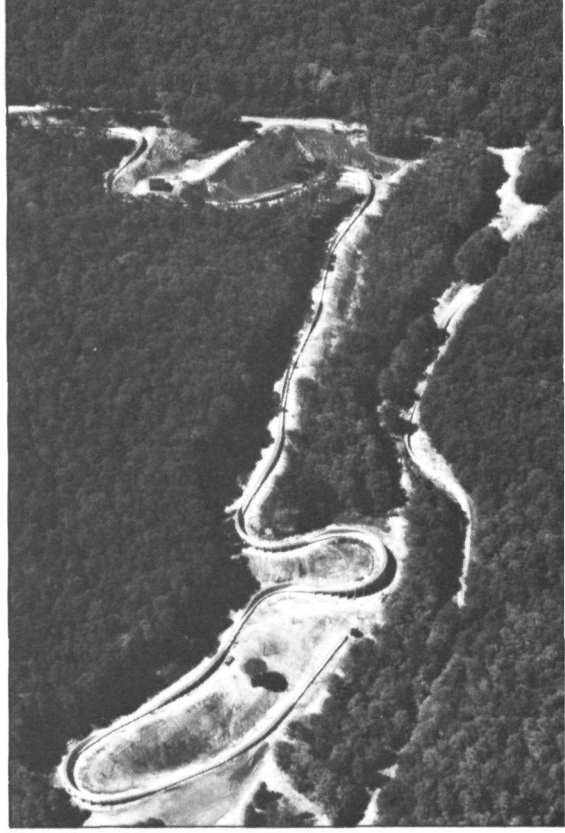
Mobile home occupants in Wichita Falls followed evacuation procedures and sought shelter in large buildings. The tornado destroyed 93 homes and nearly the entire mobile home park, but not a life was lost.

NOAA: James Purdom

At winter olympics

NOAA FORECASTERS WERE ON THE MARK

Don Witten



Bobsled and luge run, a few days before the Winter Olympics started.

Photo: Nancie Battaglia

Spectators at the 1980 Winter Olympics in Lake Placid, N.Y., were kept well enough informed about the weather not only to talk about it, but to dress for it.

The 150-square-mile area in the Adirondack Mountains where the games took place is noted for its erratic weather. It is not uncommon for snow, freezing rain, and sunshine to occur simultaneously in the area.

NOAA's National Weather Service provided special weather services for the games during February at the request of the Lake Placid Olympics Organizing Committee.

A four-man weather team set up a temporary weather station on the Olympic grounds and equipped it with the latest radar and satellite-imaging receiver equipment. Local volunteers in the area also contributed valuable information for the forecasts.

In addition to aiding the Olympic officials, the frequent short-term forecasts were tailored to keep spectators aware of dangerous wind chill and aid them in traveling to and from the Olympics. Some 50,000 spectators attended the games each day. Many of them stayed in hotels and motels outside the Lake Placid area due to its limited accommodations.

Thanks to the many forecasts, highway crews, state and local police and other authorities were able to operate at increased efficiency during a time when so many visitors were in the Lake Placid area.

Leader of the Olympic Weather Unit was Gordon Tait, on loan from the National Weather Service Office in Philadelphia. Serving with him were Jack May of the NWS Cleveland office, Steve Harned of the Raleigh N.C., office, and Richard Taylor from the New York State Department of Environmental Conservation.

Once the Olympics got underway on February 12, the weather team provided special forecasts tailored to each event. The information, including temperature, pressure, and humidity was used by Olympic officials to determine whether events should be held as scheduled.

Crosswinds blowing greater than 12 miles per hour on the ski jumps were cause enough to close the jump.

According the Tait, the competitors also used the weather information, and with a great deal of sophistication.

One example was a "buoyance index" in which temperature and humidity are used to calculate buoyancy. In using this index, skiers knew to raise their skis to gain distance when the air was less dense.

All four of the Olympic forecasters are accomplished skiers and experienced in winter sports. They gained valuable experience early in 1979 when they worked with participants in the national and World Cup Ski races held at Lake Placid.

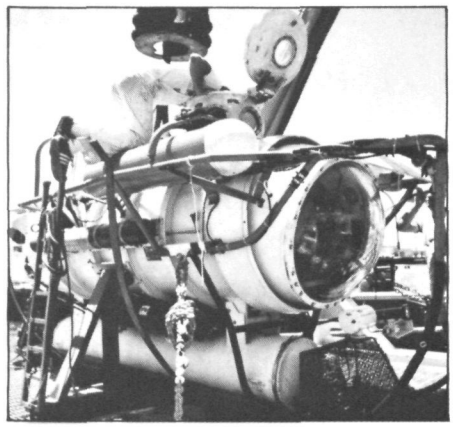
In order to disseminate the weather advisories to the public and visitors at the Lake Placid games, NOAA broadcast them throughout the area over the NOAA Weather Radio System.

Once the Olympics weather unit generated the forecasts, they sent them to the National Weather Service office in Albany, N.Y., which relayed them to a low-power transmitter located in the mountains overlooking Lake Placid.

Some 50 low-cost receivers were placed in motel and public building lobbies for public reception. During the afternoon and evening hours, NOAA Weather Radio provided a special "traveler's forecast" for those returning to out-of-town motels and hotels.

In addition to the special Olympic area broadcasts, every NOAA Weather Radio station from Albany to Pittsburgh, Pa., and as far south as Washington, D.C., carried special reports on the Lake Placid weather. They also gave brief reports on weather conditions on main highways leading to the Olympic site.

As Dr. Richard Hallgren put it, "we were happy to help with Olympics events, but our main concern was the safety and well-being of the many spectators who crowded the area in February."



PART II
Divers check out

UNDERWATER JUMP SUITS

Lt. (J.G.) Charles Gross

A member of the diving unit at Northeast Fisheries Center, this concludes his article on activities of the unit.

Divers check out small submersible (above), and open up JIM suit to show operator compartment (below).

Safety, comfort, and broader underwater horizons spur research into improved diving techniques and equipment by the Manned Underseas Research and Technology (MURT) team at NOAA's Northeast Fisheries Center, Woods Hole, Mass.

If you are not a fish, diving has inherent physiological limitations. There are two types of diving, decompression and no decompression. All divers breathing compressed air absorb nitrogen; the amount absorbed depends on the depth and time spent underwater. A diver who absorbs too much nitrogen must undergo decompression to avoid the "bends," the painful and sometimes fatal formation of nitrogen bubbles in tissues when ambient pressure is suddenly lowered—by leaving the water, for example.

Most current scientific diving is done using the Navy's no-decompression tables. These tables give divers a relatively short time under water, but these limits can be increased by reducing the proportion of nitrogen in breathing gas. Normally, air has eight parts of oxygen to two of nitrogen. Reducing the percentage of nitrogen lowers the absorption rate in the blood. This lets divers safely increase the amount of dive time.

MURT divers in cooperation with Dr. Morgan Wells, Head of the NOAA Diving Office, have field-tested a reduced nitrogen-oxygen mixture they call NOAA nitrox. The tests, in the Gulf of Maine, were successful, and in some cases doubled diving time. This mixture is available to all NOAA divers who have access to a recompression chamber and undergo proper training.

Another physiological problem for divers is nitrogen's narcotic effect. At less than 100 feet, this is a minor problem, but at deeper depths intoxication is more pronounced. To prevent this problem, nitrogen is replaced with another inert gas, helium, which has no narcotic effects, but causes the body to lose heat 10 times faster than nitrogen.

Two MURT emergency medical technicians, Cliff Newell and Roger Clifford, have designed and built an ambient pressure diving bell that can use air or mixed gas (helium-oxygen) as the breathing medium. Using this bell, scientists will be able to spend much more time in deep water than scuba allowed. Divers remain attached to the bell with air hoses and in

constant audio contact with the surface support vessel. Decompression takes place inside the bell.

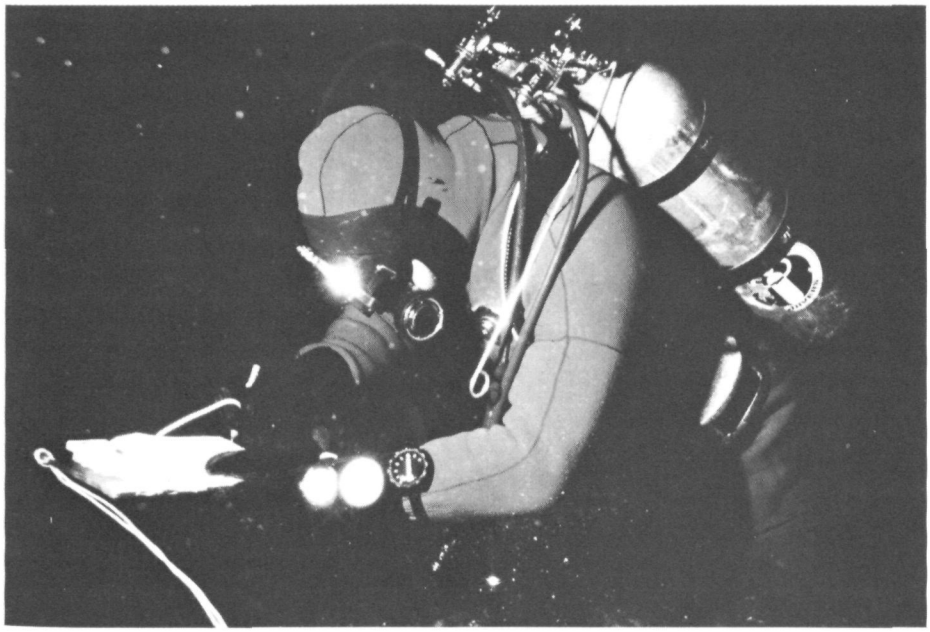
Field tests of the technique are scheduled this spring.

Perhaps the most unusual technological advance for research divers is the one-atmosphere diving suit, a one-person, tethered submersible—with arms and legs. Like a submersible, the suit is dry within and is maintained at an internal pressure of one atmosphere, thus avoiding physiological penalties for the operator who can comfortably remain at a study site for hours and return to the surface without decompression.

MURT group members have also helped evaluate an armored diving suit for scientific missions. This JIM suit (JIM is a name, not an acronym—another model is called SAM), used on offshore oil rigs for over a decade and tested to depths of 1,200 feet, was leased by the U.S. Navy from the British.

In cooperation with the University of New Hampshire, the evaluation took place at the Isles of Shoals, New Hampshire. Cliff Newell tested JIM mobility and dexterity in the open ocean environment. He found it useful for some MURT purposes; the team is looking forward to trying out similar equipment.

The state of the art in diving technology is well advanced. With the appropriate support platform dive system, and funding, vast areas of the ocean floor can be directly observed, systematically studied, and documented by diver-scientists. That's what MURT is all about.



Diver-scientist records observations of fish habitat (left); another MURT diver tests the JIM suit (above).

TOXIC CLOUDS OF THE DEEP

Richard Newell

Far below the surface of the Atlantic, on an overcast summer day in 1963, the floodlights of the U.S. bathyscaph *Trieste* swept the dark sea floor 315 miles off Boston, Mass. A dense "cloud layer" of fine particles near the bottom forced the tiny craft to cruise lower, closer to the huge boulders and steep ridges that made her search more difficult, and more risky. From time to time, thick cloud patches engulfed the craft completely.

The object of this historic search—the remains of the ill-fated nuclear submarine *Thresher*—was finally sighted. The scene, as described by *Trieste's* pilot: "A mass of twisted metal loomed so high it vanished into the cloud layers overhead."

These were among the earliest first-hand observations of sediment clouds. American scientists had previously observed them only as a mysterious background haze in some ocean-bottom photographs. The deep-water clouds were incidental to the *Thresher's* tragic end—no more than a dense fog enshrouding her silent grave. But recent research by NOAA scientists shows that similar deep-water clouds play a central role in the fate of harmful chemicals and trace metals that find their way into many of our lakes and estuaries, contaminating fish and threatening human life.

The first scientific measurements of clouded (nepheloid) bottom water in the northwestern Atlantic were made by Maurice Ewing and Edward Thorndike, oceanographers from the Lamont-Doherty Geological Observatory, just a year after the *Trieste's* successful search mission. They had long before used parts of a deep-sea camera to fabricate a device that measured particle concentration in terms of the light that reached it from a partially shielded light source. Their observations have since revealed the presence of permanent and widespread nepheloid layers, usually confined to the bottom 500 meters. The strongest layers normally occur where bottom currents are fast and turbulent, and seafloor sediments are thick.

Sediment clouds have even been found in the Great Lakes, where they were first studied in detail by two scientists from NOAA's Great Lakes Environmental Research Laboratory. The investigators, Richard L. Chambers and Brian J. Eadie, point out that the lakes are somewhat like mini-oceans, complete with shelves, slopes, and relatively deep basins, and they confined their study to the eastern half of Lake Michigan's southern basin. Concerned about the cycling of harmful substances entering the lakes from human sources, scientists are using their detailed picture of the relatively unexplored Great Lakes bottom cloudy layer.

"We found that the layer consists mainly of clay particles and biological debris," says Eadie. "It begins at the shelf-slope boundary, reaches a maximum thickness of about 10 meters at the base of the slope, where sediment deposits are also thickest, and then gradually thins out." Their observations show that about 84 percent of the cloud layer consists of sediment particles stirred up by currents. The slope and basin sediments thicken only because the particle-bearing currents usually deposit more than they resuspend. Most of the extra particles come from the shore.

The shelf region serves as a pass-through zone, up to five kilometers wide, for large quantities of particulate matter that make their way to deep water by the action of surface waves and wind-driven currents. Particle energy also comes from the thermocline, the boundary between the relatively warm, mixed surface waters and the deep, colder layer. Internal waves travel along the thermocline and impart a "rubbing" action where it meets the sloping lake bottom.

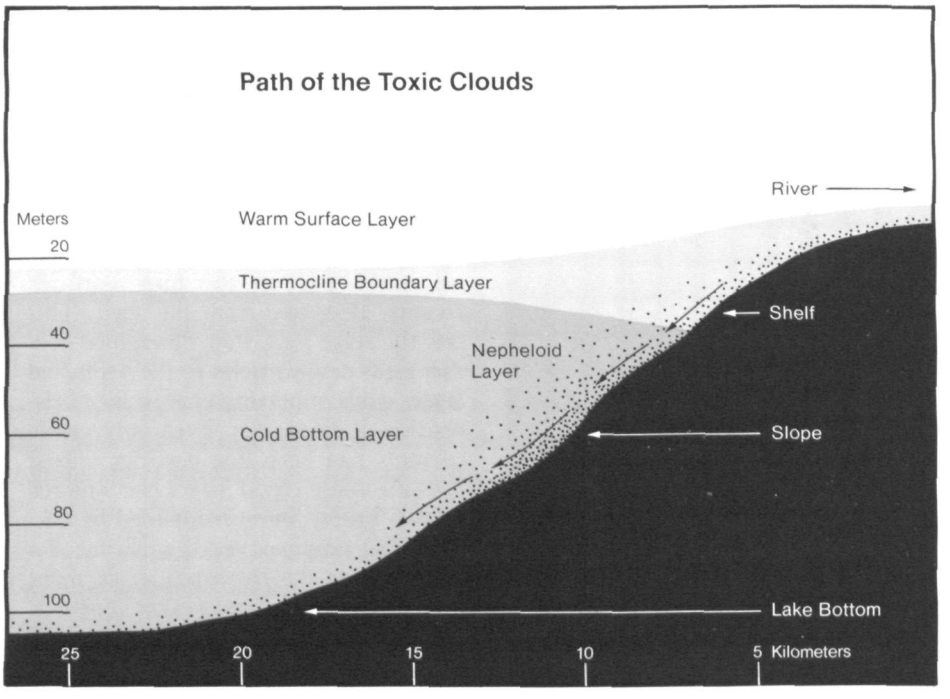
Near the top of the slope, at the average depth of the thermocline, the internal waves stir up the finer particles recently deposited from the shelf. This sets the stage for a slow downslope flow that feeds new particles to the nepheloid layer, while supplying energy for resuspension of older ones. Even very gentle currents can keep fine particles stirred up—the dense cloud layers encountered by the *Trieste* were maintained by currents that rarely exceeded a quarter of a knot. Below the thermocline, at about mid-slope depth, even weaker, but persistent, current and wave energy takes over.

Skylab photo of southwest Lake Michigan along the shoreline of Chicago, Ill. and Gary, Ind., clearly showing the clouds of resuspended sediments near the shore.

In recent years, worries about biological overproduction and premature aging of the lakes, caused by a surplus of nutrients (such as phosphorus) from detergents and human waste have been compounded by fears that toxic chemicals will contaminate the food web.

Much of the research into chemical contaminants has focused on trace metals and on polychlorinated biphenyls (PCB's), chemicals used until recently in a variety of industrial products. Trace metals are finding their way into the environment in increasing amounts, and PCB compounds already loose in the environment are likely to continue to enter the Great Lakes for many years. Polychlorinated dibenzofuran (PCDF), a little-known offspring of PCB's that is up to a thousand times as toxic, is also assaulting the lakes. PCDF is released in a highly concentrated form when PCB's are heated but not totally incinerated.

Studies have shown that most PCB's now entering Lake Michigan come from the atmosphere, attach to solid particles, and sink with them to the bottom of the lake. These particle showers are nothing new. To the crew of the *Trieste,* descending faster than the clusters of slowly sinking particles, the debris—seen in the beams of their floodlights—gave the illusion of upward-falling snow, "like a winter storm in reverse." This material is yet another source of supply for the bottom nepheloid layer, supplementing that stirred up from below or newly transported from shore.



Schematic of the nepheloid layer in southern Lake Michigan. Fine sediment deposited in the shallow water is disturbed by the mixing action of cold and warm water lays, causing the tiny sediment particles to be resuspended in the water. They thin drift slowly down the slope, ultimately coming to rest on the bottom. (Adapted from sketch by Great Lakes Environmental Research Laboratory.)

Richard A. Feely and others from NOAA's Pacific Marine Environmental Laboratory in Seattle, Wash., are helping to show how these particle showers transfer contaminants from surface waters to sea floor. Their work on trace metals in estuaries explains how surface chemicals can reach the bottom in at least two ways: biological activity and physical aggregation, or "clumping."

The scientists went to south-central Alaska to study the role of microscopic animals in the downward transfer of trace metals. Lower Cook Inlet, a large, tidally dominated estuary, is noted for its large spring and summer plankton population. "In Cook Inlet," says Feely, "we combined plankton studies with sediment trap deployments to see how plankton material containing trace metals settles out."

They found that the concentrations of copper and manganese in the settled plankton material were highest at the end of summer, when the volume of fecal pellets of the animal plankton was greatest. Says Feely, "We concluded that particles bearing trace metals are ingested by the animal plankton, concentrated in their gut, and voided as fecal material, which then sinks to the sea floor." He points out that "This type of study shows us that we need to study the biology and the chemistry together, if we're going to understand how contaminants make their way from the surface waters down to the sediments."

Feely and co-worker Gary J. Massoth also investigated the role of flocculation, the kind of particle clumping produced by electrical interactions when fresh water and sea water mix. For this study, they turned their attention to the Duwamish River Estuary in Seattle. They wanted to see if the trace metals and organic materials dissolved in the wastewater discharge of sewage treatment plants might take part in the flocculation process.

The Renton Sewage Treatment Plant, 15 miles upstream from Elliot Bay, discharges 2 to 12 percent of the wastewater in the Duwamish River. Feely and Massoth collected water samples up and downstream from the treatment plant. They found that the downstream samples produced two to three times more flocculated material with higher trace-metal content.

"Since the larger particles settle faster," Feely explains, "these findings suggest to us that the flocculation process, speeded by the presence of sewage materials, helps to move trace metals to the bottom, where they enter the estuary's nepheloid layer." Other work done by Feely, in the Gulf of Mexico, suggests that the clumping and settling of particles speeds up in nepheloid layers.

"It turns out," says Feely, "that these processess of sediment supply, aggregation, and settling are widespread, but their relative significance can be different for different locations. For instance, shore erosion isn't nearly as im-

portant to the supply of suspended particles to Cook Inlet as it is for the Great Lakes."

The spread of toxic substances, however, threatens all bodies of water. What happens to contaminated material after it settles to the bottom? Great Lakes researchers have found that this material is picked up by bottom-feeding organisms, such as alewives. These small, silvery fish are, in turn, preyed upon by larger fish, such as lake trout and salmon.

Bottom sediments give up their poisons in other ways too. Toxins can diffuse back into the water and re-collect on solid particles there. Or bacteria can colonize on fecal pellets, causing them to rupture and release their trace metals into the water.

Chambers and Eadie have also shown that the bottom nepheloid layer, with its poisonous cargo of sediments, can reinject these toxins back into the upper layer of the lake. Thus it can be just as deadly to the food web above as is the original shoreline or airborne source.

"The resuspension process is greatly speeded up during the passage of severe storms," Eadie explains. "Autumn and spring storms bring our highest winds and deepest mixing. They stir up tremendous quantities of sediments from the shelf and upper slope and mix them all the way to the surface. When this happens, the lakes get re-exposed to the same pollutants time and time again."

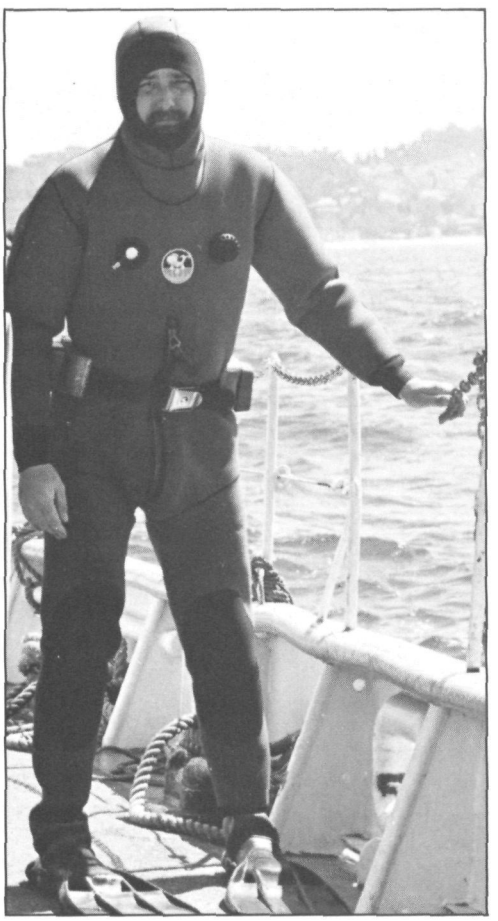
These recurring outbreaks make it more difficult to answer such questions as "How long will it take for PCB's, or trace metals, or phosphorus, to be safely buried and sealed in the bottom sediments of the lakes?"

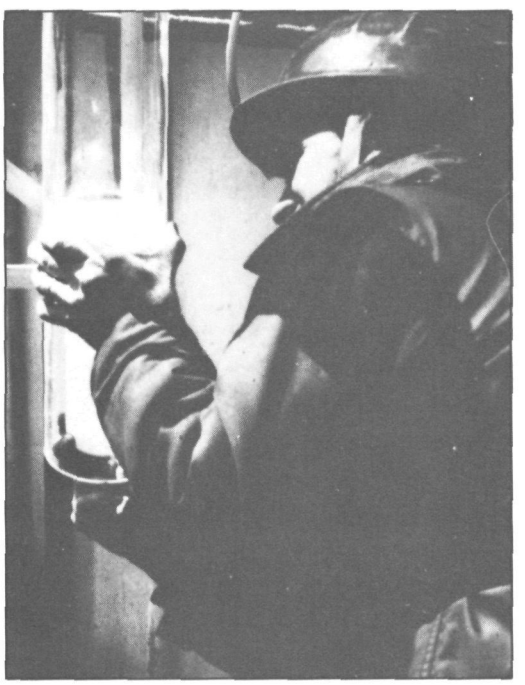
Sedimentation will inevitably do its share to clean up the waters of the Great Lakes, just as the natural flushing action of water flow-through to the sea does. But, says Eadie, "the effect of these storms makes the resuspension problem greater than we thought. It may be that the reinjection of previously trapped material is contributing as much pollution as external sources."

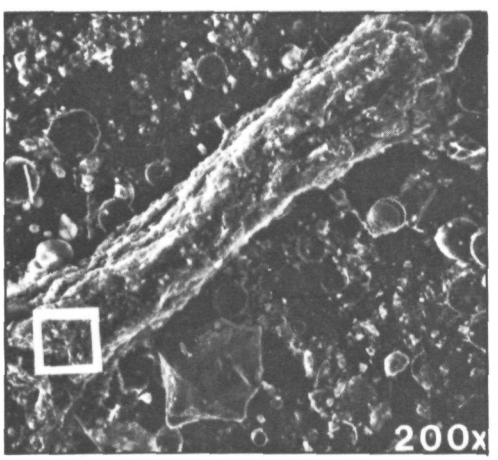
These "external sources," being human ones, are more subject to control. Various pollutant bans represent our first steps in this direction. A better understanding of nature's part in the cycling of these harmful substances will help us to understand the full part that we ourselves must play in the cleanup effort.

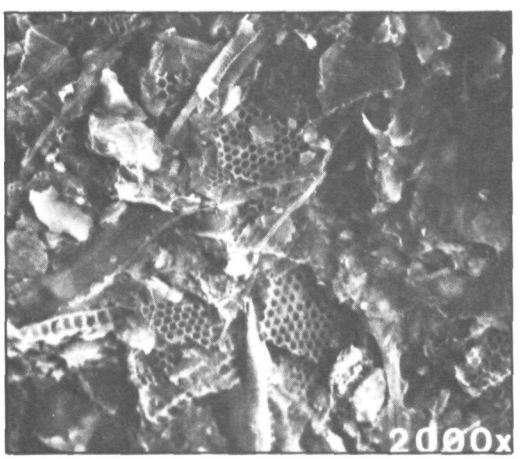
Top photos: Dr. Rich Chambers, GLERL, prepares for research dive into Lake Michigan (left); Gerald Bell helps prepare a sediment trap for deployment from research vessel.

Bottom photos: Biological activity helps transport toxic materials from surface waters down to the sediment. A microscopic fecal pellet (left) is further magnified (right) to show algae fragments containing high levels of potentially harmful trace elements.









TO CATCH THE SUN

Louise Purrett-Carroll

Man's first recorded impressions of his world placed the sun at the center of life, the controller of seasons. Veiled in the atmosphere's complexities, this deity reigned safe from man's probings. Only recently has technology given man a net to capture the sun.

Solar radiation is being studied today not just because it affects weather and climate but because it may be an important source of usable energy. But to harness the sun, you have to know how much solar radiation different locations receive, when, and under what conditions.

This is what NOAA is finding out, using its national weather station network and money from the Department of Energy. The 38 stations monitor solar radiation and collect, process, analyze and store the information.

"These measurements have many uses," according to Dr. Lester Machta, an early proponent of the solar radiation project he now heads. "Over a period of years they may reveal long-term climatic changes or effects of pollution. More important, they are beginning to prove very useful in efforts to harness solar energy —in the design both of solar energy devices and solar storage systems."

U.S. measurements of direct solar radiation began in 1902 in Asheville, N.C. Soon, regular observations were being made at five other Weather Bureau stations: Albuquerque, N.M.; Madison, Wis.; Mauna Loa, Hawaii; North Omaha, Nebr., and Tucson, Ariz.

Measurements of total radiation striking a horizontal surface began in Washington, D.C., in 1909 and continued at the same five stations that were already measuring direct radiation. In the 1920's, in response to increasing interest by agricultural scientists, more stations were added—some located at the Department of Agriculture's experiment stations, others at educational and research institutions. Over the years, the number varied, reaching a maximum of 90 in 1973. There were also hundreds of stations run by other Federal, State, local, and private organizations.

Many of these stations also measured the duration of bright sunshine. The earliest instrument was a simple device in which a glass globe focused the sun's rays to burn a tiny hole on a cardboard strip. The brightness of the sun could be gauged from the size of the burn. As the sun crossed the sky, it etched a path along the strip.

In the 1950's, this device was replaced by the "sunshine switch," composed of two photocells, one shaded from direct sunlight. Under a bright sun, the exposed sensor is much more strongly illuminated than the shaded one. On a cloudy day, the illumination on both sensors is about the same. When the contrast between the two passes a threshold value, a time recorder switches on. The time accumulated on the recorder measures the duration of bright sunshine.

The solar radiation network records spanned many years. But the data were patchy due to instrument failures and the lack of a uniform calibration standard. Now, the NOAA solar radiation network is trying to make up for lost time to meet the demands of a growing U.S. solar energy industry.

Each station has an impressive bank of measuring devices. The pyranometer, a hand-sized disk with a glass dome, measures total radiation falling on a

The standard instrument—all the radiometers in NOAA's solar radiation network are calibrated against this one, which is maintained by the solar radiation facility in Boulder, Colo.

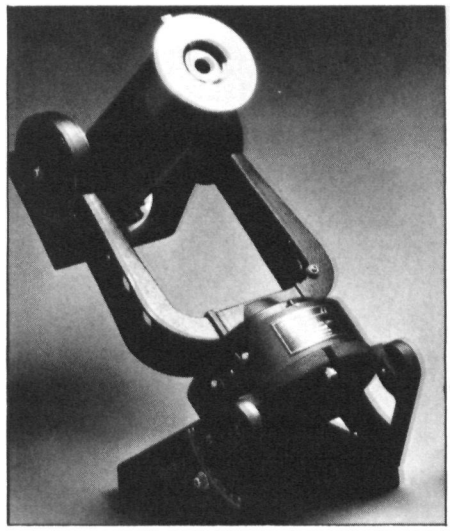


Photo: Bernard Brandt

horizontal surface from all directions. The pyrheliometer, a skyward pointed metal pipe, is mounted on a clock-driven apparatus that tracks the sun's path across the sky. The sun's rays travel down a velvety black tube to a detector at the base. Only the sun's direct rays are captured. Ten of the stations have apparatus that measures only diffuse radiation.

Radiation readings for each minute of the day are fed into a digital cassette recorder. A backup system records hourly values on paper tape, and another recorder makes a zigzag strip-chart of the same measurements. Recording the same data in three different ways reduces the chances of loss due to equipment failure. The strip chart provides a graphic check on the other recorders.

These records and maintenance log on the measuring instruments go regularly to the Center for Environmental Assessment Services in Washington, D.C., for quality control and storage. There, a staff of five meteorologists and two student aides look for inconsistencies and fill in gaps in the cassette record with data from the paper tape or strip chart.

There are also some external checks.

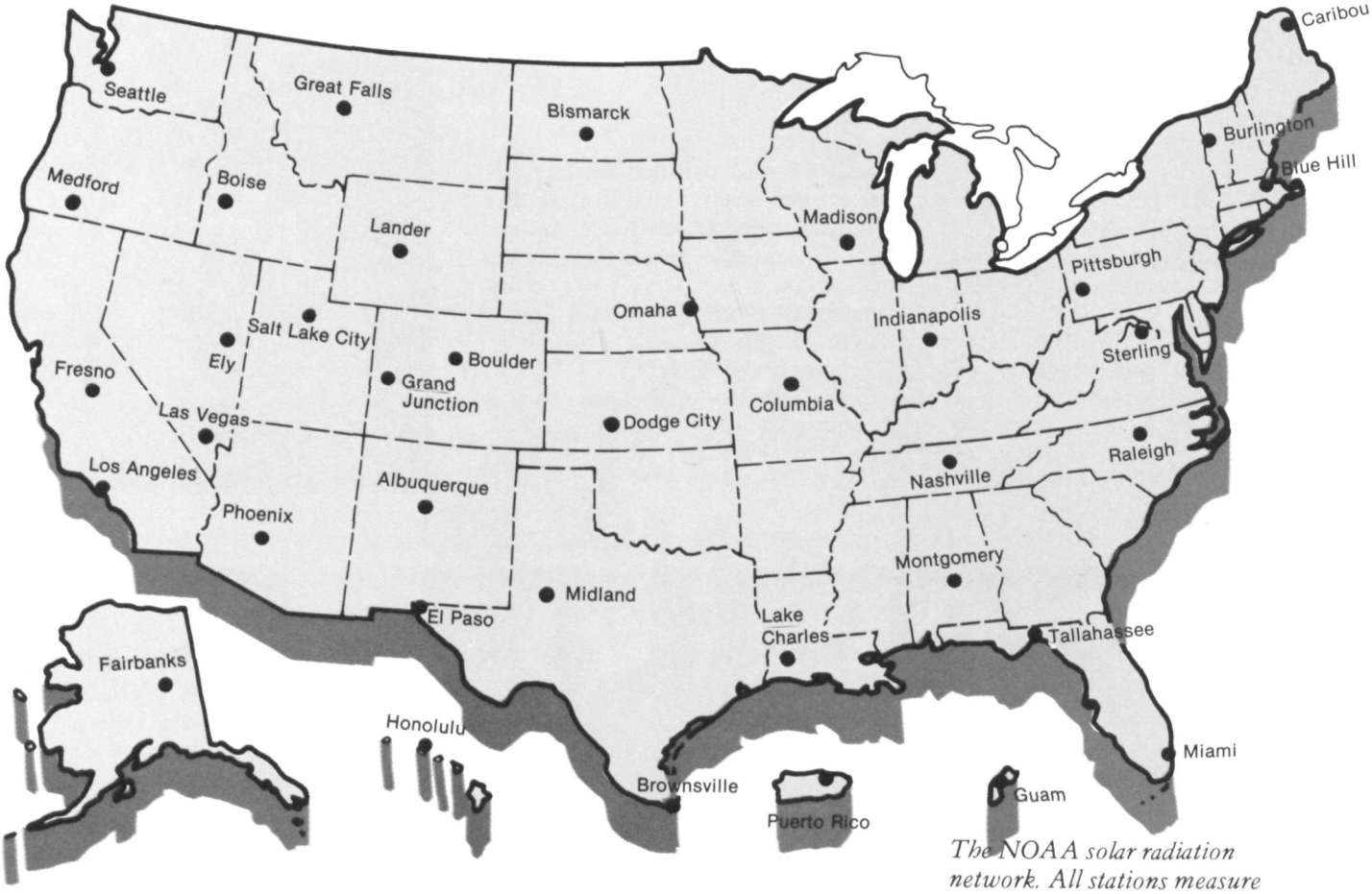
... heating by the sun is compared with heating by electric power...

A power failure may knock out all the recorders, or the three may be jotting down consistent, but erroneous, measurements from a misaligned pyranometer. Such errors can be spotted because scientists know enough about solar radiation to predict, with reasonable accuracy, the amount coming down through clear skies.

Machta has analyzed records of solar radiation under different environmental conditions—variations in the amounts of water vapor or dust in the atmosphere, for example—to derive a model that predicts the amount of solar radiation striking a horizontal surface for almost any altitude of sun and environmental state.

Using the Machta model, gaps can be filled and questionable measurements identified. The model's predictions are compared with network instruments' measurements and readings deviating from those predictions are flagged with a number that also indicates the amount of deviation.

If a station's measurements always deviate from the mark in the same way, the data are adjusted accordingly. The data are also analyzed to detect an instrument's gradual drift from desired calibration.



The NOAA solar radiation network. All stations measure both direct and global radiation; ten also measure diffuse radiation.

The center does more than detect errors, says meteorologist Martin Predoehl; where possible it tries to identify the causes and correct them. A main check is each station's meteorological record. Correction can "be a simple matter of snow or ice on the sensor," he says.

In its archives, the Center for Environmental Assessment Services stores the stations' original tapes, a magnetic tape of hourly radiation values, and photocopies of monthly data summaries. A final magnetic tape containing filled-in and corrected data goes to NOAA's National Climatic Center in Asheville, N.C., the Nation's climatic information storehouse.

In North Carolina, the data are kept in a computer format that gives hourly solar radiation data and weather data—cloud height and amount, barometric pressure, wind speed and direction, dry-bulb and dew-point temperature, and type and intensity of precipitation—for each of the 38 stations. The data are published and distributed monthly to some 270 users and are also available on magnetic tape. The series began publication in January 1977, but the center's archives began a little earlier.

From intermittent solar radiation measurements prior to the NOAA network and current knowledge, a solar radiation history has been recreated for selected sites around the country. A daily summary of radiation data from 1952 to 1976, and an abbreviated version of the meteorological data, are also stored at the climatic center.

Mathematical manipulations afford one type of quality control over the solar radiation network. Keeping the instruments accurate and consistent with one another is a second way to assure quality.

The Solar Radiation Facility, which opened in Boulder, Colo., in summer 1975, maintains standard instruments against which others are calibrated. The U.S. standard instrument, an absolute cavity radiometer, resides in a glass case here. Unlike those at the stations, this instrument can measure solar radiation in absolute units. Pyranometers and pyrhelometers convert the solar energy they receive into heat, which in turn is converted to volts, and this voltage is what is measured. In the absolute cavity radiometer, the sun's rays heat a highly absorbent cavity at the bottom of the tube, and the amount of heating by the sun is then compared repeatedly with heating of the same cavity by a known dose of electric power. So the instrument is self-calibrating.

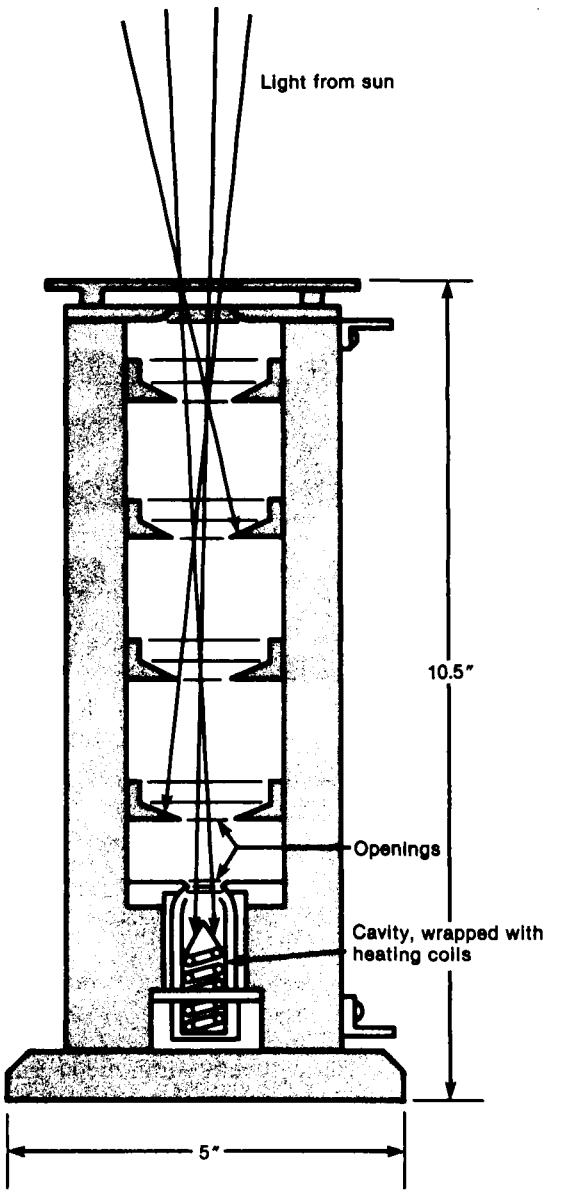
"This is the basis for everything we do," says Ed Flowers, facility head. "All the instruments in the NOAA network are ultimately calibrated against this one."

On the building's roof, dozens of pyranometers mounted in rows on white platforms soak up the bright Colorado sun. NOAA instruments go to Boulder for calibration every 15 months, but most of the roof-top battery came from other government agencies, universities, solar energy companies, and instrument manufacturers. "We're usually doing about 25 at any given time. It's good for everyone concerned, because then everyone is measuring radiation on the same basis," Flowers says. In 1978, the facility calibrated—without charge—about 80 pyrheliometers, 38 of them for the NOAA network.

The facility also conducts some experiments, such as one to determine the effect of tilting on the sensitivity of various pyranometers, and assists in outside research, like a Utah State University study of the variation of radiation in a mountain-valley system.

The group sometimes takes the initiative in encouraging uniformity among instruments, and has sponsored several meetings, at the Desert Sunshine Exposure Test Laboratories near Phoenix, Ariz., to compare and calibrate instruments among different institutions.

The solar radiation project is in full swing, and Machta is already looking for ways to improve it: "We just added instruments to measure normal incidence (rays striking perpendicular to a surface), which was requested by solar energy researchers and developers." In time, Machta hopes to add still more sensitive instruments, but for now the NOAA network provides a solid foundation for basic research on solar radiation and its effects on weather and climate and for the development of solar energy.



Cross section of a cavity radiometer. Sunlight entering the tube must pass through a series of openings that eliminate all but the direct rays. The size of the final opening is critical, because the instrument measures irradiance striking a given area. The beams that pass this final portal bounce around in the tiny space below, warming the cone-shaped covering of the cavity. The heating of the cavity by sunlight is then measured by heating it again to the same temperature, using the heating coils that encircle it. The voltage required to create this amount of heat is the measure of the sun's heating.

THE OYSTER'S HIS WORLD

Elston's illustration of tiny (2/10 mm. width) larval oyster, showing anatomical features. At top are hairlike cilia, which move rapidly for swimming and also for circulating food into the mouth—the dark area to the left, with funnel leading to digestive system in center.

Bruce Kantrowitz

Bruce Kantrowitz is Assistant Director for Communications, New York Sea Grant Institute

Ralph Elston is too young, but older members of the National Shellfisheries Association remember Nelson well. Some even studied under him.

Thurlow C. Nelson, shellfish biologist (1890-1960) was a founder of the association, and every year it remembers him by granting an award for outstanding research in shellfish biology.

Elston isn't likely to forget Nelson now. A doctoral candidate at Cornell University and New York Sea Grant trainee, Elston this year won the prestigious Thurlow C. Nelson Award for what many consider some very exciting research.

The title of his paper isn't catchy, but some say "The Anatomy, Histology, and Ultrastructure of Larval Crassotreid Oysters" has done for the study of larval shellfish what *Gray's Anatomy* did for the study of man. Elston has illustrated everything we know about the anatomy of larval oysters, following up Paul Galtsoff's classic synthesis on the adult bivalve, "The American Oyster" (1964).

Ralph studied healthy oysters to help hatchery workers spot an unhealthy one. You just can't ask an oyster to describe its symptoms, Elston points out. So you need to know how a sick one looks different from the normal ones. Students of shellfish health, of course, have long compared sick and healthy oysters, but this is the first time anyone has put down on paper what normal oyster larvae should look like.

Elston won the Thurlow C. Nelson award for some very exciting research ...

Elston's home town, Denver, Colo., is not the U.S. oyster capital; neither is Ithaca, N.Y., his present abode. Ralph never knew much about oysters. In fact, some stereotypes he held about oysters made him less than interested in studying them. A student of marine biology, Elston had always wanted to do something practical with his aquatic background, and oysters, he thought, were just too esoteric—a luxury food for the elite.

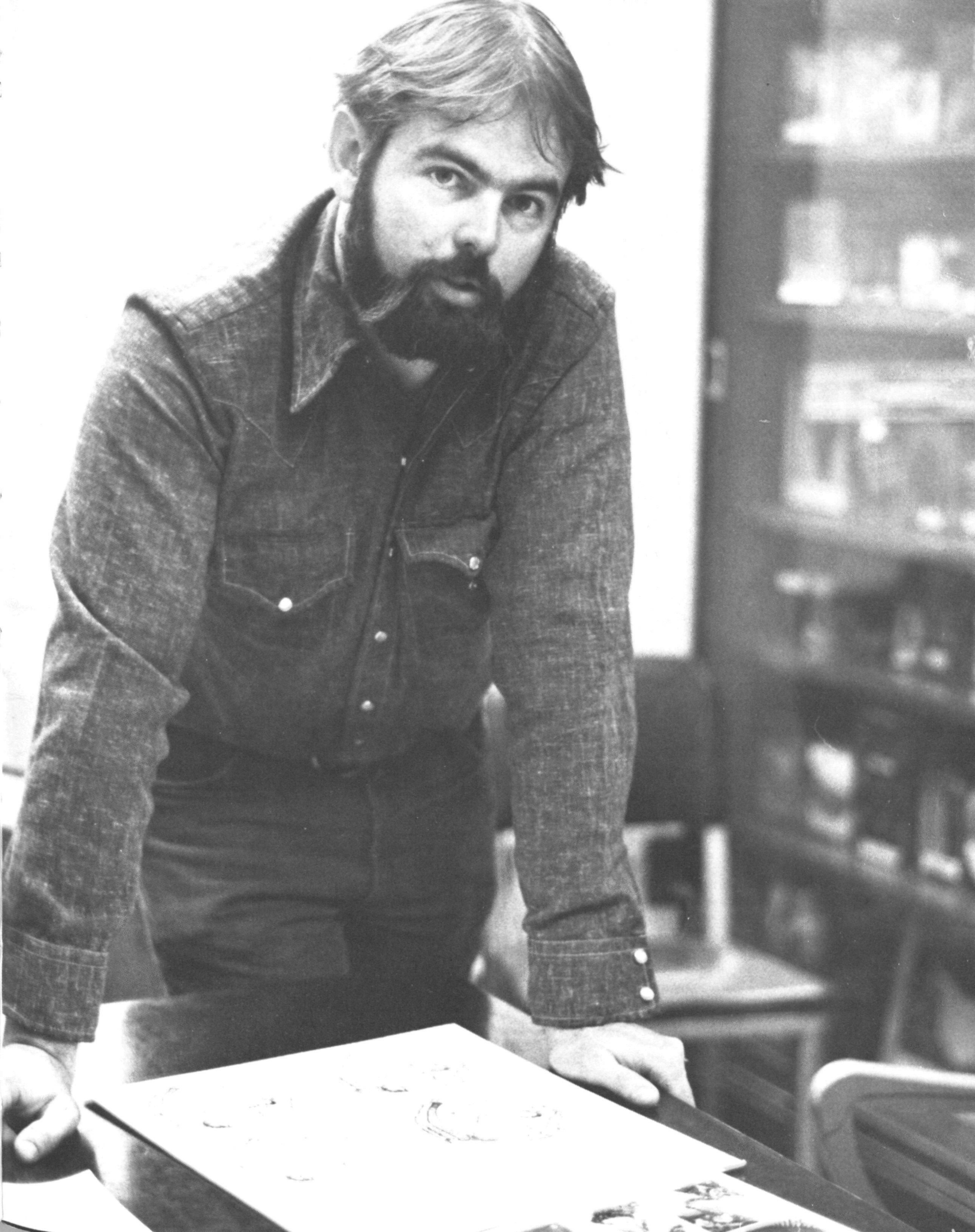
Then Ralph saw Lou Leibovitz's notice for a Sea Grant traineeship at Cornell's Department of Avian and Aquatic Animal Medicine. Ralph kept an open mind when he heard that Lou was working on oysters.

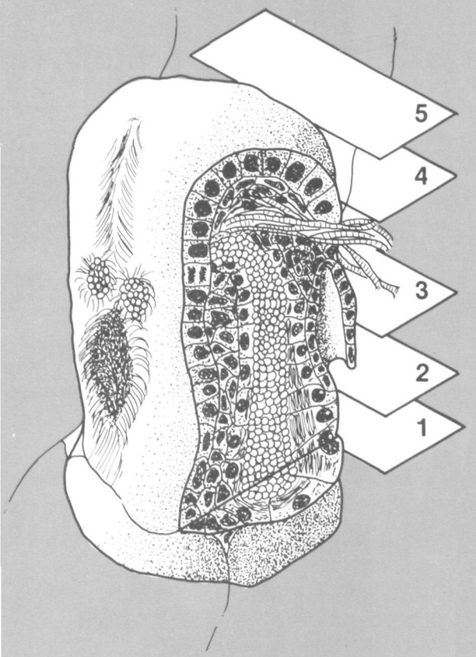
Oysters, he learned from Lou, are "the big sleepers—potentially one of our cheapest food sources." Once out of the hatcheries, and planted in intertidal waters they eat their fill of phytoplankton and grow into healthy, tasty oysters.

"Oysters are already big business. But they can become an even greater food source in the future," predicts Elston. But pollution, overharvest, and other problems tax the oyster's natural reproductive cycles. They can no longer keep up with consumer demand. Hatcheries can boost these natural cycles—but only if scientists and hatchery operators work closely together, to nurse enough larvae through the critical period of their youth, when mortality is the highest.

The most important job of the hatch-

Bruce Kantrowitz



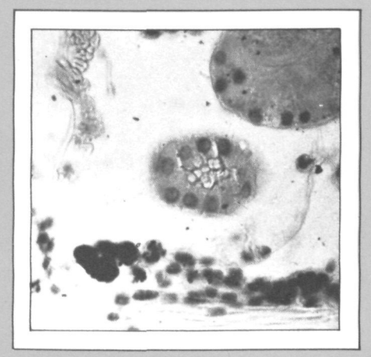


Diagrammatic representation of microscopic larval oyster foot, about 2/100 mm. in length. To make his diagrams, Elston embeds the larva in plastic, cuts it in sections, then constructs the three-dimensional drawings from the two-dimensional sections.

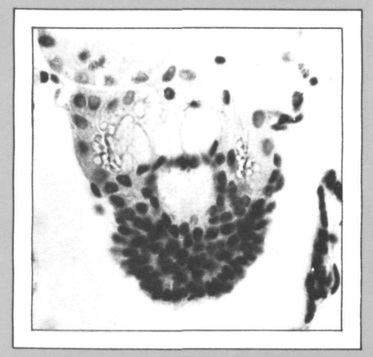
The tiny white circles in the center of the foot are the "byssal secretion", a sticky fluid used by oysters to affix themselves to hard surfaces, such as other oyster shells. The byssal fluid flows upward through two byssal ducts (one seen in this cutaway diagram) and out of the foot through two duct openings, which can be seen on the left of the foot.

The byssal ducts containing the fluid can be seen in the micrographs (below) of sections from which the drawing was constructed.

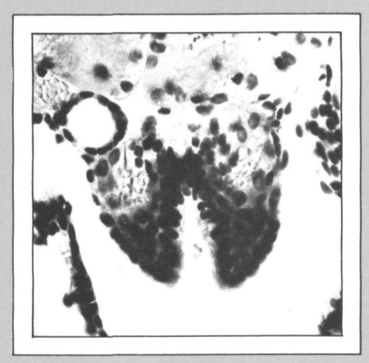
1. The oval in the center is the byssal gland, with byssal fluid in the center.



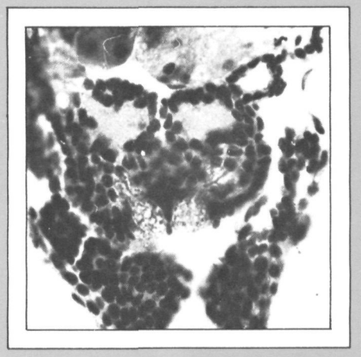
2. The byssal fluid and ducts can be seen as small circles in two groups to the right and left above the darker material.



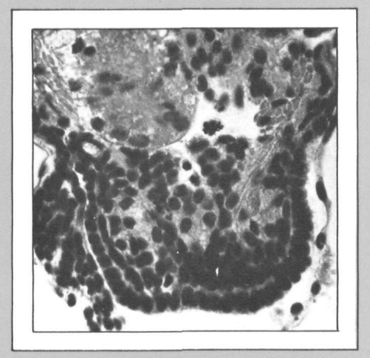
3. The two ducts continue on both sides just above the mass of darker material.



4. Close together again, they are just below the center of the photograph section of darker material.



5. This section taken above the byssal ducts does not show them.



eries is to keep their animals healthy. Every day, most hatcheries test and drain off static water, add new water and algae, then scoop up a sample of larvae to see what they can see.

"But they never could really interpret what they saw," says Elston. "The animals had to be just about dead before the hatchery people knew something was wrong."

For his first step toward understanding oyster diseases, Elston looked closely with light and electron microscopes at the anatomy of undiseased oyster larvae.

By observing with the light microscope, he could see the oyster's parts more clearly and figure out the relationship between those parts. He describes his procedure as "just basic histology."

Histology is the study of sections of tissue, serial sections taken from one end of the animal to the other—like cross sections of a tree stump. Histology gives scientists a better understanding of the whole animal's basic structure.

Then by getting an even closer look with an electron microscope, at individual cells, Elston was able to understand each organ's functions and microstructure.

Take the digestive gland, for example. It absorbs whatever the oyster's stomach grinds up. We see the stomach with a light microscope and the different stomach cells against an electron sensitive field. Explains Elston:

- *Absorptive cells* absorb nutrients: their prominent vacuole looks like a dark circle surrounded by granular material—the food stuff the cell is absorbing;
- *Secretory cells* secrete enzymes as the gland converts nutrients into fats and carbohydrates; they look like parallel lines that turn and bend;
- *Undifferentiated* cells, that don't have jobs yet, are simple structures with a large nucleus and little surrounding cytoplasm. These cells will be assigned jobs as the oyster grows.

Using the two types of microscopes—light and electron—with the technique of histology, Elston developed a detailed description of the growth of the young oyster's organ systems. One of the first explorers to the microworld of oyster larvae, he named many of these organs: the peripheral velar membrane, the posterior visceral cavity membrane, the inner and outer peripheral lobe of the velum, and the food groove.

Now when hatcheries examine larvae they'll be calling Ralph's names. They'll know what they're looking at, how it works, and what it's called.

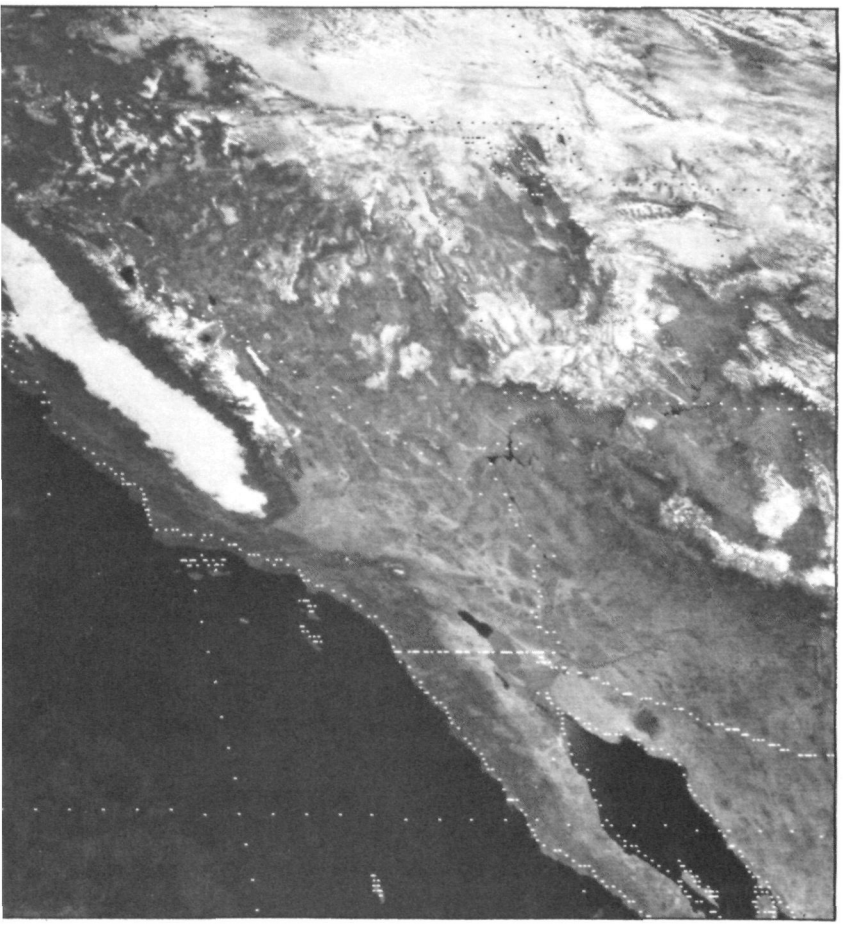
In fact, hatcheries now can go through a whole anatomical checklist—like the inspection station does every year with your car—to answer whether their animals are healthy or not. They can tell earlier about the health of their shellfish, based on subtler signs than they had before.

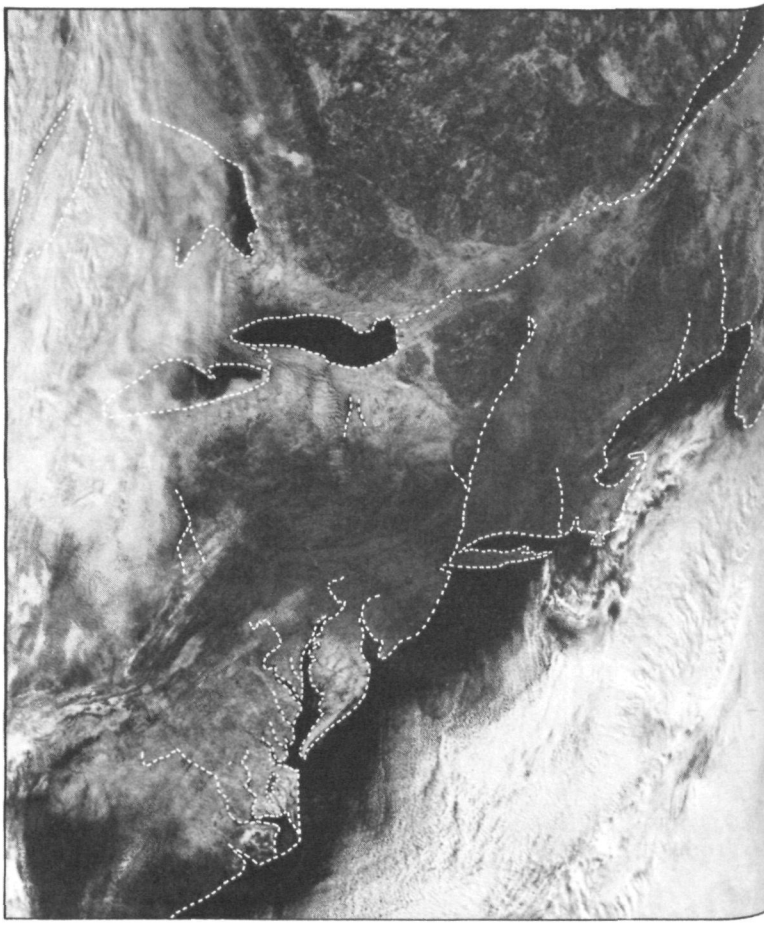
"I think of myself as a practical problem solver," says Elston. "I just want to feel like I'm helping somebody. Though I haven't personally gone to the hatcheries to work with the hatchery owners, it's enough to know my work can have some direct impact on them. I've given them a tool that I know they can really use."

If the big prize for Elston was giving hatchery owners the tools for safeguarding the health of their oysters—to help them transform the big sleeper, oysters, from a luxury food to common entree—the second prize isn't far behind. It hangs on his wall, and remembers Thurlow C. Nelson.

VIEW FROM SPACE

Snow cover significantly below normal this past winter



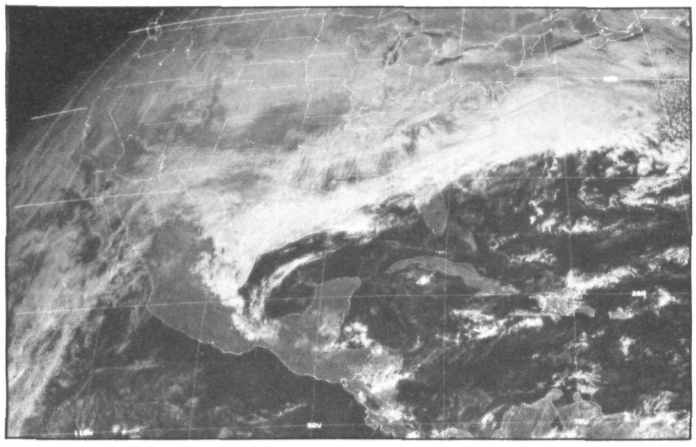


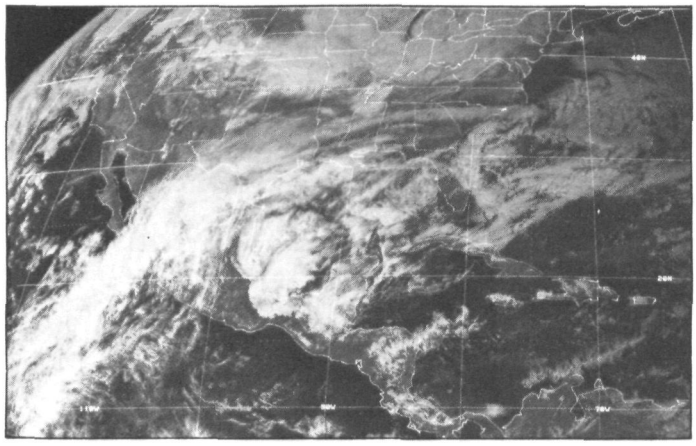
1 On January 24 almost the entire San Joaquin Valley in California was blanketed with fog, while just to the east of the valley, the higher elevations of the Sierra Nevada Mountains were snow-covered, the GOES West satellite shows.

2 The scarcity of snow in the northeast is dramatically illustrated in this TIROS-N image of February 10. There is snow on the ground in the Washington area, on most of the Delmarva Peninsula and, of course, around Lake Ontario. But in New England the ground is mostly bare.

The winter of '79–'80 as of early February, just before the winter Olympics, had been a welcome relief to many midwesterners and downeasters, following as it did several unusually severe winters. But up in Lake Placid, N.Y., it looked for a while as if there wouldn't be enough snow for the quadrennial sports extravaganza. Snow cover was significantly below normal, easing the threat of spring floods in the upper midwest and taking the pressure off local government snow clearance budgets. Many homeowners got a break, too; natural gas usage for heating was running below the previous year. Here's how NOAA satellites saw the situation . . . and how it looked at Olympic Town, U.S.A.

Whiteface Mountain near Lake Placid, showed little natural snowfall at the end of January—but the white ski trails were evidence of busy snowmaking machines as Olympic officials anxiously prepared for the big games. Two weeks later, with the games in full swing, the area was blanketed from the first big snowfall of the season.





3-4 These two images from GOES East illustrate a classic winter cold front (#3) and its aftermath (#4). The front on Jan 31 extended from Mexico across much of the Gulf and over the Carolinas, and a sharp eye may be able to see a rope cloud along the leading edge of the front over the Gulf of Mexico. Eleven days later (#4) much of the Gulf still is cloud covered as a result of the front's passage, but skies over the southeast have cleared.

Sapelo Island Estuarine Sanctuary

KEEPING NATURE NATURAL

America's National Estuarine Sanctuaries

Rich Weinstein

Rich Weinstein is a staff member of the National Sanctuary Program, Office of Coastal Zone Management

Inlets, bays, sounds poke into the land all along the U.S. coastline. Land mixes with sea, washed down on rivers and streams from mountains and hills, untouched forests, productive farms, teeming cities. Freshwater comingles with saltwater. Land's nutrients blend with the sea's, feeding tiny plants and animals that, in turn, nourish successively higher forms of life.

These coastal mixing bowls, known as estuaries, give us services worth many tens of thousands of dollars—wastewater treatment, storm protection, finfish and shellfish feeding. Ranging in size from a few square miles to the 193-mile-long Chesapeake Bay, estuaries sustain more than two-thirds of the commercial and sport fish landed in the United States.

Here, many of us have waded, hunted, fished, gotten rowboats stuck, or wrinkled our noses at the odor of millenia of sediment on their floors.

Yet, despite their ecological and recreational importance in our world, few truly pristine estuaries remain for scientists to study and for the rest of us to enjoy. Unprotected, they bear the marks of man's passage, the eventual if accidental receiving grounds for civilization's pollutants.

As part of the Coastal Zone Management Act of 1972, the Congress set up a system for ensuring that relatively untouched estuaries would be set aside for scientific study and education. Congress hoped knowledge from these "laboratories" would inform future management decisions concerning estuaries and their preservation.

The act allows the Federal Government to make 50 percent matching grants to States so that they may select, own, and operate these areas. Each sanctuary is classified according to what is termed its "biogeographic" area, that is, whether its scientific role is primarily

biological, hydrological, or geological. The range of sanctuaries represents each of the biogeographic provinces within the United States.

Not surprisingly, individual sanctuaries differ from each other not only physically but also in the way they are managed, and in the opportunities they afford for scientific research.

The first estuarine sanctuary funded under the program is located in South Slough, Ore. An arm of Coos Bay, its 4,200 acres include timber land, fresh water marshes, and wide, shallow, saltwater marshes containing an extremely high population of bottom dwelling invertebrates. The sanctuary also has river otters, more than 80 species of land and water birds, 40 species of trees and shrubs, and the only major island in Coos Bay with a climax forest.

The sanctuary is managed by the South Slough Estuarine Sanctuary Management Commission, made up of representatives from several State agencies, local agencies, and private organizations. Dr. Delane Munson, the manager, oversees all activities within the sanctuary.

Although the South Slough Estuarine Sanctuary has been in operation only a short time, Dr. Munson believes it has already benefited research. As the only undeveloped area in Coos Bay, South Slough is "unique," according to Dr. Munson. "It is the only place where the water quality is even good enough for oyster culturing. It's the only place where people doing research in natural rate processes—the balance between what nutrients estuaries absorb and what they give up—can do their work."

Dr. Munson values the National Estuarine Sanctuary Program in general. "We must understand more about estuaries in order to protect them," he says, "because estuaries are breeding grounds for food fish for man." He mentions the dungeness crab, a popular seafood. "If we know more about estuaries, we'll know more about how the ecosystem affects the crab and about how the removal of a part of the ecosystem, say through chronic oil pollution, will affect the crab. In other words, the importance of set-aside areas is that scientists can compare the life within them with life in more polluted areas to see the effects of these pollutants."

Dr. Leon Barzin, a scientist working at South Slough, feels that research in the South Slough Estuarine Sanctuary is just getting started. "Ten years from now," he foresees, "the amount of research here will be greater. The fact of the sanctuary's existence, and that it is part of a Federal program, will undoubtedly bring in more funds for basic research. This will serve as seed money to bring in funding from outside sources. As the sanctuary is more publicized, scientists and sources of funding will be ever more anxious to come here."

Dr. John Gallagher feels South Slough is developing into an outstanding research facility. An associate marine scientist at the University of Georgia's Marine Institute at Sapelo Island, Dr. Gallagher is on leave to work with the Environmental Research Laboratory at Corvallis, Ore.

Dr. Gallagher considers South Slough one of the Oregon coastline's primary sites for the study of salt marshes and would like to see the sanctuary attract more researchers.

"Researchers look for three things," he explains, "an environment for research, accessibility between the field and the laboratory, and a place to live near the research area. In South Slough, the environment to study salt marshes is excellent. With Oregon's Institute of Marine Biology laboratory so convenient, lab accessibility is fine. Living quarters are not the best, but they are looking better." He finds the sanctuary area "esthetically pleasing."

In contrast to the developing South Slough research area, Sapelo Island, Dr. Gallagher's home base, has been known as a wetlands research park for over 20 years. The 7,400-acre estuarine sanctuary, which encloses the island's Duplin River, is only part of a State and Federally protected ecosystem that includes nearly all of Sapelo Island, Blackbeard Island to the northeast, and Wolf Island directly to the south. Upland areas within the sanctuary are alive with oaks, loblolly pine, turkey, and deer. The area's salt marsh is covered with cordgrass and black needle rush.

The Director of Georgia's Marine Institute, Dr. Donald Kinsey, is cautious about the immediate benefits of making Sapelo a part of the national program. "We now have some protection that we didn't have before," he said, "but over the short term, I think giving Sapelo sanctuary status has had no profound effect. It was fine for research before and it still is."

In the long run, however, Dr. Kinsey believes that "because Sapelo Island has the greatest tidal flow anywhere on the East Coast and is the most pristine salt marsh in the world, keeping it that way in perpetuity will be incredibly beneficial for research in the future, and sanctuary status will ensure its existence."

One of the largest projects at Sapelo was a study funded by the National Science Foundation that dealt with the productivity of a salt marsh. The director of this project, Dr. Lawrence Pomeroy, believes, like Dr. Kinsey, that sanctuary creation has not yet had much effect. "The research facilities have not been changed, since few dollars have come in," he explained. The operations money NOAA provided was, by mutual

Sapelo Island Estuarine Sanctuary

Egret rests in sheltered habitat at Sapelo Island Estuarine Sanctuary in Georgia.

agreement, funneled primarily to the sanctuary's educational program.

Like any new undertaking, the sanctuary has had its initial difficulties. "There have been problems," Dr. Pomeroy admitted, "but they've been minor. There are stringent regulations on any research that changes the environment, but such limitations really are necessary and they are not a very serious problem."

Another researcher who experienced some of the problems of sanctuary establishment is Dr. Jean Ann Nichols, who had to suspend one approach to studying bottom-dwelling nematode worms because of restrictions placed on the introduction of radioactive isotopes into the marsh.

The estuarine sanctuary program has definite benefits, however, says Dr. Nichols. The most important of these is that within the sanctuaries scientists do not have to fight with industry over the access to land.

The effect of sanctuary status at Old Woman Creek, Ohio, had been substantial. Not only the research program but the idea behind it was established from scratch. "Fresh water estuaries are a new concept," says Dr. Charles Herdendorf, director of Ohio State University's Center for Lake Erie Research. "They're different from fresh water river mouths, because within estuaries there is a mixing of the water in a semi-enclosed basin. Also there is some evidence of a 'tidal' influence, which, in this case, is caused by winds. Old Woman Creek is a perfect example of a fresh water estuary and, as such, is an ideal place for study."

The Old Woman Creek Estuarine Sanctuary is relatively small—only 637 acres—but because it is on the heavily populated shores of Lake Erie, it is extremely valuable as an outdoor laboratory and educational center.

Old Woman Creek is the only sanctuary established with an administration that includes both a sanctuary manager and a sanctuary biologist, Dr. David Klarer. According to Dr. Klarer, Old Woman Creek is one of the best fresh water estuaries still relatively unaffected along the shores of Lake Erie. Because of this, he feels baseline monitoring will be useful as a control against which to measure pollution effects and pollution control along the whole of Lake Erie, and, in fact, all of the Great Lakes.

"My real goal here," says Dr. Klarer, "is to increase our knowledge of fresh water estuaries and of the coasts of the Great Lakes in general."

Even before its involvement in the National Estuarine Sanctuary Program, the Rookery Bay Estuarine Sanctuary, near Naples, Fla., already had proven its enormous value in coastal management decisionmaking. In response to encroaching development in the early 1960's citizens of Collier County, formed the Collier County Conservancy, which, assisted by

the National Audubon Society and the Nature Conservancy, bought up what is now the core area of the Rookery Bay Estuarine Sanctuary.

In 1970, a marine research station was set up on the land and extensive studies of the area were conducted by the Conservation Foundation. More than once the foundation helped to persuade the Army Corps of Engineers and the now defunct Florida Department of Pollution Control to refrain from giving building permits to developers in the South Florida area, thereby protecting the mangrove forests and waterways.

Now under the control and protection of the State, the sanctuary covers over 8,500 acres, including a large, mangrove-filled bay and two creeks. The Rookery Bay Marine Research Station is located on an 80-acre area still owned by the County Conservancy, and is directed by Bernard J. Yokel, who lives and works at the site.

In an *Audubon Magazine* article, Yokel characterizes his role as describing the ecological systems in and around the bay and their value to the community. "All of us here at the station have to figure out how to keep these systems functioning," he explains. "Where can changes take place? In other words, we have to decide what parts of this area can be developed without destroying the natural systems. If certain areas are too fragile to support development, we have to stand up and say so."

Like the scientists associated with the National Estuarine Sanctuary Program, Yokel feels sanctuaries have clear benefits. "I would say there are three main advantages: the first is that the sanctuary now includes more land, which not only provides a greater preserved area for research, it also makes the core area more pristine by assuring that the waters draining into this area will be cleaner.

"The second benefit is that becoming part of the national program will focus attention on this system and the good and useful programs it's providing for Collier County and the State. And, third, there is now a more favorable attitude for research support because funding sources know the research will be conducted in a National Estuarine Sanctuary."

Among the organizations that have funded research at Rookery Bay is the Environmental Protection Agency. The man in charge of EPA's research projects at Rookery Bay, Dr. Ariel Lugo, has an unusual perspective on the National Estuarine Sanctuary Program because he is also co-chairman of the Federal Committee on Ecological Reserves, dealing with many protected areas similar to and including estuarine sanctuaries. Dr. Lugo agrees with Bernie Yokel that buying more land will produce many positive long-term benefits for the sanctuary, but he feels that, as is the case with Sapelo Island, "over the short term, sanctuary status has produced very little difference."

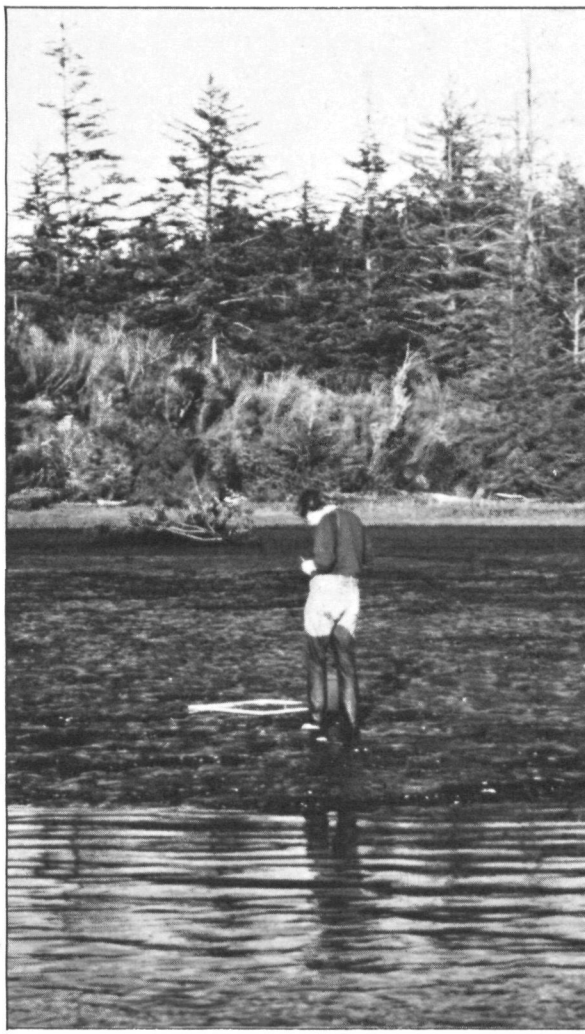
Dr. Lugo's view of the National Program's network of estuarine sanctuaries is especially interesting because he is an employee of the Federal Government: "Frequently scientists don't like Government coming in, but as long as the requirements are reasonable—not arrogant—it is desirable. Scientists want the checks that government hands out." This attitude was echoed by Dr. Keith Bedford, who confessed that he, and most scientists, were guilty of a "gimme-your-money-and-leave-me-alone" attitude.

Dr. Lugo adds this feeling is partly justified. "When dealing with research aspects, big Government mustn't always decide where money should be put," he said. "This is research by decree."

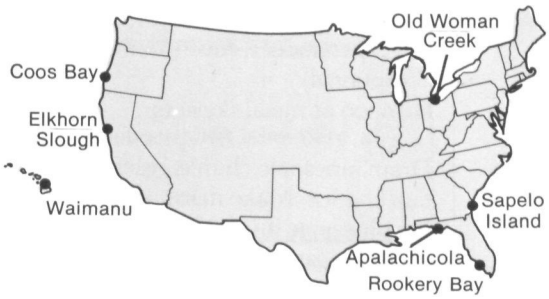
"As many options as possible should be stressed," he says. "In the past, there was a tendency to have lands set aside for just one purpose, with other uses there prohibited. Areas set aside for science must have more options, not just science." The estuarine sanctuary program allows multiple functions, for example, recreational or even commercial, to the extent that they do not interfere with the sanctuaries' primary purposes of research and education.

The most pristine of the sanctuaries to receive funding is Hawaii's Waimanu, a 5,900-acre, mountain-enclosed stream valley that drains into the Pacific Ocean. So isolated is the area that it can be reached by land only by a strenuous 6- to 8-hour hike. The sanctuary's land is still being acquired, and there is no ongoing research.

There are also two areas proposed as estuarine sanctuaries. Apalachicola River-Bay in Florida and Elkhorn Slough in California. The extensive research now going on at university-related facilities near both is expected to continue if they receive sanctuary status.



South Slough Estuarine Sanctuary



Cyndi Ray starts algae research at South Slough Estuarine Sanctuary in Oregon (top). Chart (bottom) shows wide distribution of present estuarine sanctuaries.

Whether you're feeling très *continental or really downhome, some little known and little tried species of fish in the United States can provide you with a delicious, nutritious meal.*

Alaska pollock and Maine whiting (also known as silver hake) are members of the cod family. Although found across the country from each other, they still maintain the cod family tradition of good taste and nutrition.

A delicacy in Europe, where they are "farmed," mussels are found in abundance along the northern coast of the United States and Canada. Many people with good taste find them similar to oysters or clams.

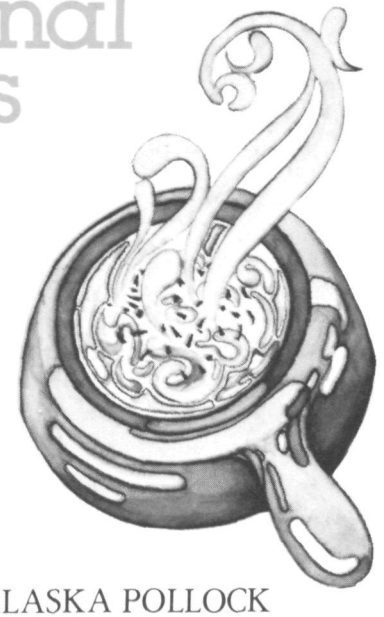
Shark, considered a vicious movie star in the United States, is considered a delicious meal in many other countries of the world. About 62 species inhabit the waters of North America. Especially pleasing about shark meat are its lack of bones, firm texture, leanness, mild taste and the adventure of serving it on your table.

Unconventional taste delights

SHARK TERIYAKI

2 pounds fresh shark fillets, cut in 1 inch chunks
1 can (16 ounces) pineapple
1/2 cup soy sauce
1/2 cup sherry (optional)
2 tablespoons brown sugar
1 teaspoon ground ginger
1 teaspoon dry mustard
1 clove garlic, crushed
1 green pepper, cut in 1-inch squares
Cherry tomatoes, mushrooms, onions (optional)
Bamboo or metal skewers

Drain pineapple chunks reserving 1/4 cup of juice. Make marinade by combining pineapple juice, soy sauce, sherry, brown sugar, mustard, and garlic. Pour marinade over fish chunks. Cover and refrigerate fish for at least 1 hour. Drain fish and reserve marinade. Thread fish chunks, pineapple chunks, and green pepper squares alternately on skewers. Include cherry tomatoes, fresh mushrooms, and onion wedges if desired. Cook over hot coals or under broiler about 4 inches from source of heat for 5 minutes. Baste with marinade. Turn and cook for 5 minutes more or until fish flakes easily when tested with a fork. Serve as a main dish on a bed of rice or alone as an hors d'oeuvre. Makes 6 entree servings or 18 to 20 hors d'oeuvres.



ALASKA POLLOCK CHOWDER

1 pound Alaska pollock fillets
1/4 cup chopped bacon
2 tablespoons bacon drippings
2 garlic cloves, finely chopped
1 can (1 pound 12 ounces) stewed tomatoes
2 cans (8 ounces each) tomato sauce
2 cups water
2 cups potatoes O'Brien mix
1/4 teaspoon thyme
Liquid hot pepper sauce to taste
1/4 cup soy sauce
1/2 cup dry Vermouth (optional)

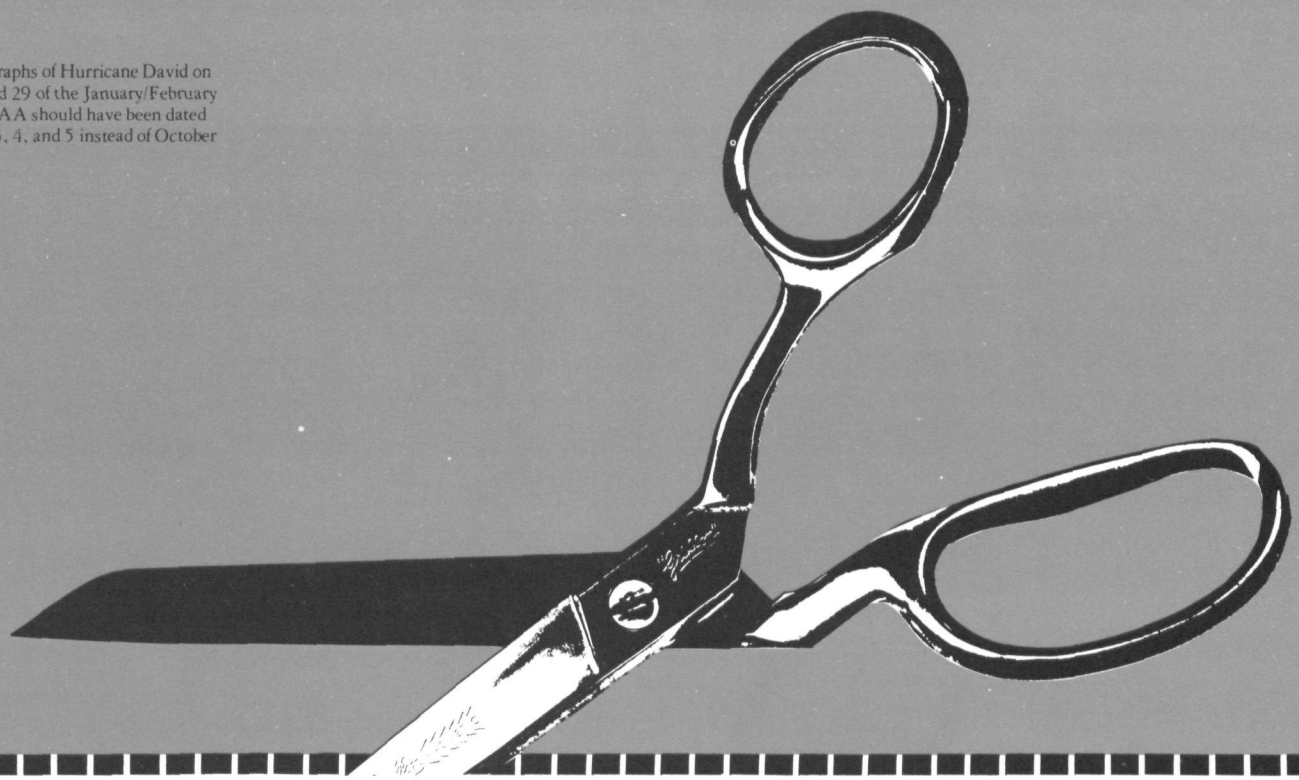
Thaw fish if frozen. Cut into one-inch pieces. Fry bacon until crisp reserving 2 tablespoons bacon drippings. Add garlic and cook with reserved bacon drippings until tender. Add remaining ingredients except Vermouth. Cover and simmer 30 minutes. Add fish and Vermouth. Cook an additional 10 minutes. Sprinkle with parsley. Makes 6 servings.

MUSSELS WITH LINGUINE

2 1/2 qt. mussels in shells (approx. 75)
1/4 cup olive oil
2 cloves garlic, finely minced
2 onions, thinly sliced
2 lemons, thinly sliced
2 large cans (1 lb. 13 oz.) Italian tomatoes, mashed
1 can (6 oz.) tomato paste
1 1/2 tablespoons oregano
1/8 teaspoon red pepper
1/2 teaspoon black pepper
2 teaspoons dried basil
1 1/2 teaspoons salt
2 cups red wine
2 lbs. linguine

Sort, scrub, and rinse mussels; trim byssus. Saute onion and garlic in 6 quart kettle. When onion is golden and soft, add lemon slices, tomatoes, tomato paste, basil, oregano, red wine, salt, and peppers. Simmer over low heat for 25 minutes with pot covered. Add wine and simmer without the cover until sauce thickens—15 to 20 minutes. (Sauce may be prepared in advance—up to the addition of the mussels.) Add mussels to sauce, cover and cook over medium-high heat until the mussels open—approximately minutes. Cook linguine according to package directions and toss with 2 tablespoons olive oil to prevent sticking. Arrange linguine on a large tray. Cover with cooked mussels and tomato sauce. Serve immediately. Makes 8-10 servings.

Erratum:
The photographs of Hurricane David on pages 28 and 29 of the January/February issue of NOAA should have been dated September 3, 4, and 5 instead of October 3, 4, and 5.



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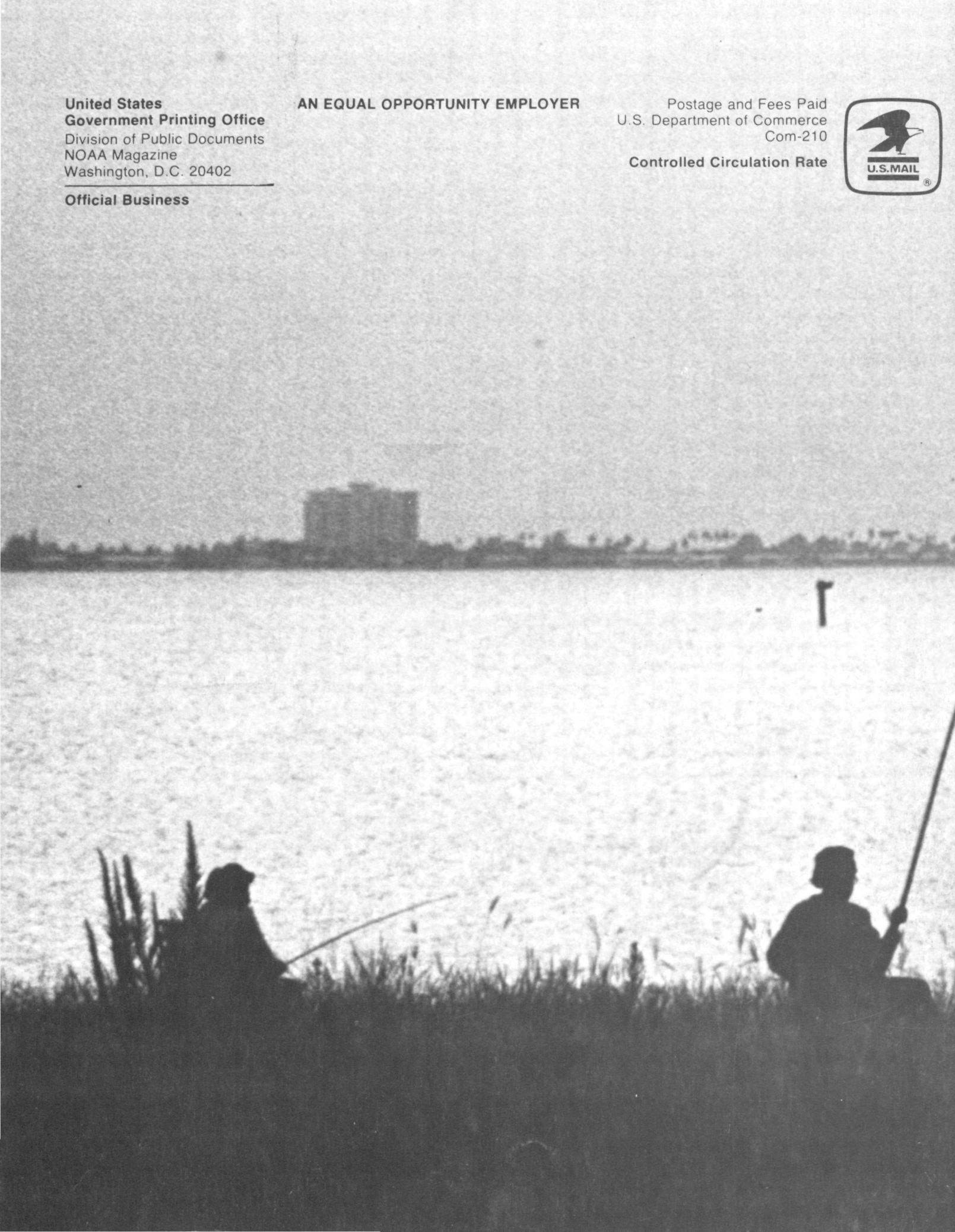
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